ROLE OF DUAL ENERGY COMPUTED TOMOGRAPHY (CT) IN CHARACTERISATION AND MANAGEMENT OF RENAL STONES

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Dedicated

to

my Family

&

Teachers

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LIST OF ABBREVIATIONS

DECT	Dual Energy Computed Tomography
kvp	Kilovoltage peak
mSv	Millisievert effective dose
PCNL	Percutaneous Nephrolithotomy
ESWL	Extracorporeal shock wave lithotripsy
Ca HA	Calcium Hydroxyapatite
Ca Ox	Calcium Oxalate
UA	Uric acid
CaP	Calcium phosphate
FOV	Field of view
AR	Attenuation Ratio
DER	Dual Energy Ratio
USG	Ultrasonography
CECT	Contrast enhanced computed Tomography

ABSTRACT

Background: The prevalence of renal stone disease has been increasing worldwide. Dual Energy Computed Tomography (DECT) has emerged as a valuable tool in comprehensive evaluation and management of urolithiasis by providing accurate stone characterization.

Aim: The aim of present study is to determine the role of Dual energy computed tomography in characterisation and management of renal stones.

Materials and Methods: The present study was conducted in the Department of Radiodiagnosis at Dayanand Medical College and Hospital. A total of 53 patients scheduled to undergo surgical extraction of renal stones were included in the study. . After the characterization of the calculus via Dual-energy computed tomography, surgical extraction was done. The stones chemical composition was evaluated through laboratory examination and then compared to the findings of DECT.

Results: The sensitivity and specificity of Dual CT in detecting calcium oxalate stones is 68.7 % and 86.6 %, in calcium hydroxyapatite is 48.5 % and 100%, in uric acid stone is 100 % and 98.6 % respectively.

The sensitivity of dual CT for diagnosing calcium stones with respect to non calcium stone was 90.28% while specificity was 100%. The level of similarity between Dual ct and lab analysis of stone type shows a kappa value of 0.55 which shows a good similarity.

Conclusion: Dual-energy CT (DECT) presents a valuable capability to differentiate calculi based on their composition, aiding urologists in guiding treatment decisions effectively. It has high sensitivity of 90 % and specificity of 100% in detecting calcium VS Non calcium stones with accuracy of 91%.

Keywords: Dual energy ratio, Dual energy computed tomography, Stone attenuation value, nephrolithiasis.

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INTRODUCTION

1.1 Background

Urolithiasis have been a persistent issue for humans for centuries, with the earliest recorded cases dating back to 4000 B.C.[1] The prevalence of urinary stone disease has been increasing worldwide and affects a diverse range of individuals. Factors contributing to this rise include sedentary lifestyles, high body mass index (BMI), poor nutritional intake, and insufficient physical activity. This condition is more prevalent in both developed and developing nations, particularly in regions with hot climates and among white population.[2,3,4] The peak incidence in males occurs between the ages of 40 and 60, while in females, it peaks around age 30. Additionally, the incidence rate among the pediatric population can reach up to 3%.[5]

The main symptom of urinary stone disease is a sudden, intense colicky pain in the flank that radiates to the hypochondrium. However, those with staghorn calculi might only feel mild lumbar pain. This pain is usually severe, fluctuating based on the patient's position and the stone's location. It does not improve with changes in posture or non-narcotic medications and is frequently accompanied by nausea and vomiting.[2,6]

Nephrolithiasis or urolithiasis occurs when urine becomes oversaturated with minerals, leading to the formation, growth, aggregation, and retention of crystals within the kidneys. About 80% of kidney stones globally are made up of calcium phosphate (CaP) and calcium oxalate (CaOx). Other common types include struvite stones, which account for approximately 9%, cystine stones at 10%, and uric acid stones at 1% of all cases.[8]

The key prognostic factors for urinary stone disease are the size and location of the stones. The probability of a kidney stone passing on its own largely depends on its size; stones smaller than 5 mm often can be managed with conservative treatment. As stones increase beyond 4 mm, the necessity for a urological referral grows. One should seek assessment

and treatment from a urologist if stone is greater than 5 mm or if stone hasn't cleared within two to four weeks.[2,9]

1.2 Pathogenesis

Renal stones form due to urine supersaturation and physicochemical changes. When urine becomes supersaturated, solutes precipitate, leading to nucleation and crystal formation. Factors such as high levels of calcium, phosphorus, uric acid, oxalate, cystine, and reduced urine volume raise the possibility of crystal formation in nephrolithiasis. Preventing supersaturation of these stone-forming substances can help avert the development of nephrolithiasis.[10]

Stones cannot form unless calcium oxalate crystals nucleate inside the kidney, according to nearly all urolithiasis cases. Oversaturation of urine with calcium oxalate causes nucleation. The primary factors determining urinary saturation with calcium oxalate are the renal outputs of calcium and oxalate. The concentration of these substances, rather than their quantity, plays an important role in crystal nucleation. Additionally, supersaturation levels are influenced by the volume of urine or the amount of water consumed.[8]

The primary causes of stone formation include abnormally low output of citrate (hypocitraturia) or magnesium (hypomagnesuria), and excessive urinary excretion of calcium (hypercalciuria), oxalate (hyperoxaluria), or urate (hyperuricosuria). Dehydration, which leads to low volumes of highly concentrated urine, can also contribute to stone formation. Additionally, an elevated urinary pH, which can be due to conditions like renal tubular acidosis or infections, proceed to stone production. Nephrolithiasis is characterized by a high concentration of crystalline material (97%-98%) and an organic matrix that provides a foundation for crystal deposition.[11]

1.3 TYPES OF RENAL STONES

Around 80% of all kidney stone cases are calcium oxalate (CaOx) or calcium phosphate (CaP) stones. Uric acid (UA) stones account for roughly 9%, and struvite stones make up about 10%. The remaining 1% consists of cystine stones, drug-induced stones, and ammonium acid urate stones.[8]

Kidney stones can be categorized into two types: calcium-containing calculus and non-calcium-containing calculus.[12]

Calcium-Containing Calculus

- Calcium oxalate: 60%
- Hydroxyapatite: 20%
- Brushite: 2%

Non-Calcium-Containing Calculus

- Uric acid: 7%
- Struvite: 7%
- Cystine: 1%

TABLE 1: Characteristics of Different Types of Urinary Tract Calculi [5]

Composition	Frequency (%)	Imaging Pearl	Causative Factors
Calcium	70–80	Wide range of densities and gross morphologies	Numerous, including primary hyperparathyroidism, chronic diarrhea, and distal renal tubular acidosis
Magnesium ammonium phosphate (struvite)	15–20	Staghorn calculus refers to a struvite calculus involving the renal pelvis and extending into at least two calyces	Infection
Uric acid	5–10	Pure uric acid stones are radiolucent on radiography	Gout, small-bowel disease, and high body mass index
Cystine	1–3	May contain low-attenuation foci (voids) on CT	Cystinuria
Medications and their metabolites	1	Indinavir can be radiolucent even on CT	Prolonged or excessive use of some medications

1.4 Imaging

An imaging procedure should be performed on all patients who are suspected of having a stone in the urinary tract to ascertain location, size of calculus and rule out obstructive uropathy .[13]

Radiography

When evaluating acute onset flank pain, the kidney-ureter-bladder radiograph was the first examination of choice for many years. Radiopaque calculi make up around 90% of urinary tract calculi. Radiography may reveal nonspecific secondary indications of renal colic. These can include intestinal ileus, slight splinting, and fluid around the kidneys obstructing the contour of the kidneys. Unfortunately, due to the possibility of small radiopaque calculi being obscured by bowel contents, gas, osseous structures, and overlying soft tissues, radiography has only been reported to be about 60% sensitive overall in the identification of urolithiasis.[14]

USG

Ultrasound is especially advantageous for pediatric and pregnant patients, as well as those experiencing recurrent episodes of urolithiasis, because it does not involve ionizing radiation.[15] Moreover, ultrasound's effectiveness is not dependent on the stone's composition, since most stones will appear echogenic and cast shadows if they fall within the imaging field. Ultrasound can detect stones as small as 0.5 mm, identified by echogenic spots and shadowing within the urinary tract.[16] Colour Doppler imaging can produce a twinkle artefact in the shadowed region seen on grayscale images, which prove the existence of a stone. This artifact, thought to arise from narrow-band intrinsic machine noise, correlates with the stone's surface composition.[17-19]An elevated false-positive rate could be caused by utilising 5-mm unenhanced CT scans as a reference standard, even though Doppler's twinkling artefact increases ultrasound's sensitivity for stone detection compared to gray-scale imaging alone.[20] [21]

In addition to detecting stones, ultrasound can identify secondary effects like obstruction, infection, or abscess formation. Similar to CT scans, ultrasound can show obstruction as ureteral and collecting system dilation at the stone's location.[22] However, it can be difficult to distinguish between dilation caused by obstruction and dilation without obstruction on ultrasound.[23,24]

CT-SCAN

The benefits of non-contrast computed tomography (NCCT) over alternatives like ultrasonography and plain radiography are numerous. These benefits include the elimination of the need for intravenous contrast, easy availability, fast acquisition times, and very high sensitivity and specificity (over 95% and 96%, respectively) for detecting stones.[25] NCCT can identify almost all stones regardless of their location, size, or composition, with the primary exceptions being indinavir stones and pure matrix protein stones, which are typically found in patients undergoing treatment for HIV.[26]

One significant advantage of CT is its ability to diagnose secondary signs of obstruction, such as hydroureteronephrosis and perinephric edema. [25] CT can also assess renal or urothelial tumors and congenital urinary tract abnormalities.[25] Additionally, CT is reliable in ruling out other causes of acute abdomen, such as tubo-ovarian pathology and appendicitis, providing a clearer view of abdominal structures than other imaging modalities.[27]

While stone standard CT may overlook or under-describe some disorders, contrast-enhanced CT can pick up on a wider range of abnormalities. It can also differentiate between distal ureteral calculus and phlebolith. However, the radiation risk associated with CT scans is a particular concern for younger patients and those with recurrent disease, despite the numerous advantages it offers. [28]

DECT

Dual-energy computed tomography (DECT) represents an advancement in contrast-enhanced computed tomography (CECT) technology, offering radiologists a new edge in image interpretation. DECT utilizes a second X-ray spectrum to analyze the elemental composition of materials within the imaged body part by acquiring two separate energy levels (keV). This allows better characterization of tissues and materials, enhancing diagnostic accuracy and providing deeper insights into the composition of structures within the body.[8]

DECT has recently been developed as a practical method that can aid in accurately identifying the components of urinary stones in vivo. [29]

DECT is an innovative, cost-effective, and straightforward technique that uses two spectral X-ray beams (140kV and 80-100kV) to create two distinct images of same tissue or region. These images are produced on basis of absorption and attenuation indices of various material compositions. DECT has been applied in numerous areas, including material differentiation (such as bone removal in angiography[30], detection of bone marrow edema[31], and reduction of metal artifacts[32], material decomposition and iodine mapping (for lesions in the lung, liver, adrenal glands, and bowel pathologies)[33], and material separation (for characterizing urinary stones).[34,35] The specific dual-energy ratio of stones allows DECT to differentiate their chemical nature, as shown in previous studies.[33]

Given the importance of knowing the composition of urinary stones in determining the appropriate management and treatment for patients, dual-energy CT can play a crucial role in guiding treatment planning. It helps in reducing unnecessary surgical interventions or identifying the need for surgery. Therefore, this study was designed to determine the pure composition of renal stones using DECT.

AIM AND OBJECTIVE

- The aim of present study is to determine the role of Dual energy computed tomography in characterisation and management of renal stones.

REVIEW OF LITERATURE

DECT emerges as a pivotal tool in urology, furnishing clinicians with detailed and precise information crucial for diagnosing and planning treatment for various urological disorders. This narrative review offers an overview of DECT's promising applications in the realm of urological diseases.[36]

Many studies been conducted in past to evaluate the efficacy of DECT in urolithiasis. Some of them are mentioned below:

In 2010, **Thomas C**. et al found that low-dose dual-energy CT accurately identified most urinary stone compositions, though one calcified stone in an obese patient was misinterpreted, and a struvite calculus was incorrectly identified as cystine. Despite these exceptions, the method provided a mean radiation dose of 2.7 mSv, with generally acceptable image quality, albeit reduced in larger patients. They concluded that while effective, the protocol is best suited for nonobese individuals due to decreased image quality in obese patients.[34]

Ascenti G. et al. successfully characterized renal stones using DECT. In their study, the researchers evaluated a stone-targeted, low-dose protocol using a dual-energy CT scanner to detect and characterize urinary tract stones. They enrolled 39 patients (20 men and 19 women, aged 22-87 years, with an average age of 47 years) who had suspected renal colic and ureteral stones identified on low-dose unenhanced CT. The study concluded that DECT attenuation values enabled the characterization of all ureteral calculi, effectively distinguishing between uric acid and calcium salt stones. Moreover, they found that the increase in radiation exposure from dual-energy scanning could be significantly reduced with a limited stone-targeted dual-energy protocol.[35]

Researchers **Li ZX et al.** looked at 84 gout patients who had DECT (dual energy CT scans of the urinary tract) in order to find out whether kidney stones were present. They found nephrolithiasis in 48.8% of subjects, with 63.0% having pure UA stones. Patients with stones had more acute attacks and longer gout durations. Urine abnormalities were prevalent, including hypomagnesuria (55.0%), low urine volume (51.8%), and unduly acidic urine (44.4%). Hyperuricosuria was less common (12.2%). Logistic regression identified longer gout duration and low urine pH as nephrolithiasis risk factors, with female gender being protective. This highlights the high prevalence of UA stones in gout patients and the significance of disease duration and urine pH as risk factors.[37]

Kambadakone AR et al. reviewed the literature on urolithiasis and its treatment using DECT. It is commonly practiced to treat uric acid stones (<400 HU) by making the urine more alkaline in order to help them dissolve. Procedures like ureteroscopy or Percutaneous Nephrolithotomy (PCNL) are routinely used to handle cystine stones and non-uric acid stones (>1000 HU, >1 cm). The adequate methods for treating non-cystine, non-uric acid stones (<1000 HU, <1 cm) frequently involve ureteroscopy or Shock Wave Lithotripsy (SWL). This underscores the importance of accurate stone characterization through Dual CT in guiding appropriate treatment plan for different types of stones. [38]

Ramire Giraldo JC said The distinctive CT number ratio (CTR) of a material has a significant impact on DECT's material identification capabilities. The CTR is the comparison of a material's CT number in the low-energy and high-energy images, divided by one another.[39]

Stolzmann P Scheffel H, discussed the management of patients can be significantly altered by the identification of uric acid calculi using DE ratios. DECT is generally advantageous for patients with familial metabolic

diseases. Patients suffering from cystinuria, who can develop cystine-based renal calculi, should pay special attention to this. Many people can be effectively treated medically with captopril, eliminating the demand for invasive procedures like Percutaneous Nephrolithotomy (PCNL) or Extracorporeal Shock Wave Lithotripsy (ESWL). These procedures are expensive and come with risks such renal haemorrhage, fibrosis, or hypertension.[40]

Shinde S found Urologists can use ESWL to target stones with heterogeneous compositions, as these stones are more responsive to fragmentation during treatment. It is essential to include this information in the medical report. Homogeneous stones, such as cystine stones and specific types of calcium stones, are notably difficult to fragment with ESWL.[41]

The success of ESWL is discussed by **Renner C** which shows it is contingent upon the composition of the stone, which influences the type of fragments that are formed during the decomposition of the calculus. ESWL is unable to dissolve denser calculi composed of calcium phosphate or cysteine, necessitating surgery. calcium oxalate dihydrate, Calcium oxalate monohydrate, and calcium phosphate stones are all examples of calcium-based stones. The effectiveness of ESWL can be limited by the hard composition of certain stones, such as calcium oxalate monohydrate, struvite, calcium oxalate dihydrate, and uric acid stones. Specifically, cystine, calcium oxalate monohydrate stones being resistant to fragmentation and are usually treated with ESWL only if the stone size is 1.5 cm or smaller.[42]

Duan et al. found that third-generation dual-source DECT, with its enhanced spectral separation, improved the differentiation between uric acid and non-uric acid stones. They also noted that third-generation DECT

devices could help reduce image noise in patients with larger body habitus.DE ratios are used to distinguish between uric acid stones and calcium-based stones. A key feature of DECT equipment in imaging urolithiasis is the graphical representation of these DE ratios. The DE ratio is determined by dividing the attenuation value of the calculus at 80 kV by its attenuation value at 140 kV. Stones containing calcium are identified by a DE ratio greater than 1.24.[43]

In a blinded, prospective study**, Eric S. Wisenbaugh (2014**) compared the accuracy of conventional CT and DECT in anticipating the composition of renal stones. The study involved scanning 32 renal stones with known compositions using standard CT at 120 kilovolt peak (kV[p]) and fast-switched kilovolt DECT at 80 and 140 kilovolt peak (kV[p]).Analysis was possible for 27 stones. Single-energy CT correctly identified 14 out of 27 stones (52%), while DECT accurately identified 20 (74%). DECT performed better in distinguishing between uric acid and non-uric acid stones, with a success rate of 93% compared to 40% for single-energy CT.[44]

To determine how well DECT differentiates between uric acid in the urine and calcified stones, **Zeng et al. (2016)** performed a meta-analysis. The analysis included nine studies, comprising 609 stones from 415 patients. The pooled sensitivity for differentiating uric acid (UA) from non-UA stones was 0.955, with a specificity of 0.985, and an AUROC of 0.9901. For calcified stones, the pooled sensitivity was 0.994, specificity was 0.973, and the AUROC was 0.9915. The study's authors found that DECT accurately and noninvasively characterises uric acid and calcified stones in the urine..[45]

Habashy et al. (2016) conducted a study to assess whether DECT analysis of urinary calculi composition led to changes in patient management. Out of 585 DECT scans performed, 393 (67%) revealed urinary tract calculi. We found 303 patients with symptomatic stones after omitting tiny asymptomatic renal stones. There were 273 cases of calcium calculi (90.1%), 19 cases of uric acid calculi (6.3%), and 11 cases of mixed calculi (3.4%). Fifteen patients with uric acid calculi underwent dissolution therapy, resulting in successful outcomes for 12, thus avoiding surgical intervention. The authors concluded that DECT-based prediction of urinary tract calculi composition is vital for identifying candidates suitable for dissolution therapy, impacting management decisions in 5.0% of cases and successfully avoiding surgery in most instances.[46]

Dawoud et al. (2017) conducted a study on effectiveness of DECT in the treatment of renal stones. This study was done on 40 patients, with mean age of 33 years, and included 18 males and 22 females from the ages of 24 to 65. Firstly , all patients underwent standard low-dose renal stone CT scans, which were followed by DECT examinations that utilised single-source dual-energy technology with rapid kilovoltage toggling between 80 kV and 140 kV. The results illustrated DECT's consistent capacity to differentiate between cystine, calcium oxalate, and uric acid stones. In particular, 22 stones were identified as containing calcium oxalate, 10 as cystine, and 8 as uric acid. Nevertheless, DECT encountered difficulties in identifying mixed-composition stones in three cases and in differentiating between calcium oxalate and calcium phosphate in four stones. Upon comparison with crystallography results following stone passage or extraction, these discrepancies were detected, indicating that calcium oxalate stones were misdiagnosed.[47]

Using in vitro stone analysis as a reference, the current gold standard for urinary stone analysis, **Hasan et al. (2019)** compared DECT's diagnostic accuracy to that of in vitro stone testing. A 128-slice dual-source CT scanner was employed to conduct DECT examinations on 373 patients. Analysing the attenuation ratios between the high and low kilovoltage peak values allowed the stones to be classified into four types: hydroxyapatite, calcium oxalate, cystine, and uric acid. In 35 patients, stone retrieval was accomplished through spontaneous passage or surgery. Among all patients, DECT identified 136 hydroxyapatite, 160 calcium oxalate, 57 uric acid, and 20 cystine stones. A total of 35 patients underwent in vitro stone analysis, which identified 8 hydroxyapatite, 18 calcium oxalate, 6 uric acid, and 3 cystine stones. Upon comparison of DECT results with in vitro analysis, 32 patients (91.4%) had their stone types correctly identified, while 3 patients (8.6%) had their stone types incorrectly identified. DECT was capable of accurately detecting all uric acid and cystine stones.[48]

In study by **Mohammed M Dawoud et al**,[49] they provide reliable distinction between uric acid , Ca Oxalate and Cystine stones. It predicted chemical composistion of the stones in 40 patients as 22 stones composed of calcium oxalate, 10 stones composed of cystine and 8 stones composed of uric acid. DECT failed to differentiate Ca oxalate from Ca phosphate in 4 stones and also failed to identify mixed composition stones in 3 stones.[49]

A study by **Mehra et al. (2020)** outlined the function of DECT in the estimation of kidney stones. Following the localization of renal stone, the anatomic region harbouring the stone was subjected to targeted dual-energy scanning. Two distinct energies (80 and 140 kVp) were scanned concurrently, and the resulting data was reconstructed using the available tools. When examining renal stones, DECT's sensitivity, specificity, and

diagnostic accuracy were determined to be 95, 96, and 98%, respectively.[50]

Rudenko et al. (2020) tested five indices, including the dual energy ratio (DER), to see how well DECT predicted the cofiguration of urinary stones. The study involved 91 patients. For calcium oxalate monohydrate (COM) stones, the results using the DER were 83.3% sensitivity, 89.8% specificity, and 86.8% accuracy. For calcium oxalate dihydrate and calcium phosphate stones, the results were 88.2% sensitivity, 92.9% specificity, and 91.2% accuracy. For uric acid stones, the DER results were 0% sensitivity, 98.8% specificity, and 97.8% accuracy. For struvite stones, the results were 60% sensitivity, 95.3% specificity, and 93.4% accuracy. For COM stones, the sensitivity, specificity, and overall accuracy were 95.2%, 89.8%, and 92.3% when discriminant analysis with five indices was used; for COD stones, the corresponding values were 85.3%, 96.4%, and 92.3%; and for struvite and uric acid stones, 100% in all three categories were achieved. The study draw to close that DECT is a valuable tool for accurately detecting composition of urinary stones, with accuracy and specificity ranging from 85% to 100%.[51]

The function of DECT in evaluating the compositions of renal stones was examined in a prospective cohort research by **Shawky et al. (2021).** The study included 30 patients, 20 of whom were male and 10 of whom were female, and their ages ranged from 16 to 79. Before DECT utilising single-source dual energy with quick kilovoltage switching from 80 to 135 kVp was implemented, traditional single-energy exams were carried out (100-120 kVp). Out of the 37 stones that were analysed, DECT successfully identified 24 as calcium oxalate, 8 as uric acid, and 5 as cystine. All uric acid stones were correctly identified by DECT. However, DECT misclassified 2 stones as calcium oxalate, later confirmed as calcium phosphate by crystallography. Additionally, DECT failed to identify mixed

compositions in 2 stones, initially diagnosed as calcium oxalate and cystine stones. Statistical analysis indicated a highly significant agreement between DECT and crystallography (p-value > 0.001).[52]

To assess the utility of third-generation, dual-source, DECT in the characterization of renal calculi, **Shalini et al. (2022)** carried out a prospective study in which 50 patients underwent ex vivo renal stone estimation using Fourier transform infrared spectroscopy (IS) as the gold standard. They discovered that the kidney stone's mean attenuation ratio was 1.57 ± 0.25. Of the 50 patients, 39 were predicted to have calcium-containing stones, 4 to have cystine stones, and 7 to have uric acid stones based on DECT imaging. 43 individuals had calcium-containing stones, while 7 patients had uric acid stones, according to IS analysis. In our investigation, the DECT had an accuracy rate of 90% for calcium stones and 100% for uric acid stones. It was discovered that the DECT has a 92% positive predictive value in determining the chemical makeup of renal calculi.[53]

To create a technique for renal stone characterization in vivo, **Avinav Bharati (2022**) carried out research. The ability to differentiate renal stones in vivo, particularly calcium subtypes, is a significant advantage for more informed treatment option selection. A dual energy CT scanner was used to do ex vivo scanning of 50 removed renal stones. With a sensitivity of 81% and 83%, respectively, the developed approach was able to characterize calcium oxalate monohydrate and the combination of COM and calcium oxalate dihydrate (COD) stones non-invasively in patients. Additionally, the technique could distinguish between Uric, Cystine, and mixed stones with sensitivity values of 100, 100, and 85.71%, respectively. They came to the conclusion that the dual energy CT-based approach they had devised might distinguish between subtypes of calcium stones that cannot be distinguished using single energy CT images.[54]

Using stone composition analysis as the reference standard, **Euler et al. (2023)** evaluated the precision of low-dose dual-energy computed tomography (DECT) in distinguishing uric acid kidney stones from non-uric acid kidney stones in two generations of dual-source DECT. A total of 203 patients' 227 stones were examined. An study of the makeup of the stones revealed 212 non-uric acid and 15 uric acid stones. The average dimensions and volume were 4.7 mm×2.8 mm and 114 mm3, in that order. When uric acid stones were compared to non-uric acid stones, there was a substantial difference in CT attenuation ($p<0.001$). DECT accurately classified 227 kidney stones out of 227 total kidney stones. The merged results for sensitivity, specificity, and accuracy were, in order of significance, 1.0 (95%CI: 0.97, 1.00), 0.93 (95%CI: 0.68, 1.00), and 0.99 (95%CI: 0.97, 1.00). Out of 84 stones with a diameter of less than 3 mm, 82 were properly categorized. The effective dosage was 2.43 ± 0.86 mSv, while the mean DLP was 162 ± 57 mGy*cm. They came to the conclusion that even at small stone sizes, low-dose dual-source DECT showed excellent accuracy in differentiating between non-uric acid and uric acid stones.[55]

Ali et al. (2023) investigated DECT for characterizing renal stones in vitro, confirmed by X-ray diffraction and Fourier transform infrared spectroscopy. DECT accurately predicted uric acid stones with ratios between 1.02 to 1.1 and calcium-containing stones with ratios between 1.24 to 1.65. For dual energy index, ranges of 0.00174-0.00918 and 0.0495-0.1497 predicted UA and calcium stones respectively. DECT correctly characterized 2 out of 40 UA stones and 38 out of 40 calcium stones, aligning closely with confirmatory methods. This underscores DECT's potential for accurate differentiation of renal stone compositions in vitro.[56]

Johnson et al. (2024) analyzed the composition of renal calculi preoperatively using DECT and compared it with biochemical stone analysis in 81 patients. CT predictions categorized stones into "uric acid," "struvite," "calcium oxalate," and "calcium carbonate apatite" based on DE ratio. Spectral analysis and DE ratio successfully differentiated calculus types with statistically significant p-values. Both of methods were effective, spectral analysis slightly outperformed DE ratio, particularly for mixed stones. DE ratio ranges were derived as 0.9–1.1 for uric acid stones, 0.9–2.3 for mixed stones, and 1.0–2.4 for calcium stones. The study concluded that spectral analysis offers a practical approach to predict calculus composition preoperatively, potentially preventing unnecessary surgical interventions. [57]

MATERIAL AND METHODS

SOURCE OF DATA

It was a prospective study conducted on patients who were diagnosed with renal calculi and scheduled to undergo surgical extraction of stones in Dayanand Medical College and Hospital, Ludhiana.

Inclusion Criteria:

1) Patient diagnosed with renal calculi on ultrasound, plain x-ray or Intravenous Pyelogram (IVP) and scheduled to undergo surgical extraction of stones

Exclusion Criterion

1) Pregnancy
2) Medically managed patients,
3) Patient not willing to give consent,
4) Patients in whom laboratory analysis of the stone is not feasible.

METHOD OF COLLECTION OF DATA

Patients who had clinical suspicion of renal stones and referred to department of radiodaignosis were included in study. Relevant detailed history and consent was taken from each patient and recorded in performa. All patients were imaged under Dual energy CT in our department.

The following features of Kidney stones were evaluated on dual CT images:

1) Site & Location of calculus
2) Size of calculus
3) Attenuation ratio of calculus on Dual CT

DURATION OF STUDY- One and a half years.

OUTCOME: The high precision of DECT in characterizing the chemical nature of the renal stones and determining the management plan.

STATISTICAL ANALYSIS:

Data was described in terms of range; mean ± standard deviation (± SD), median, frequencies (number of cases) and relative frequencies (percentages) as appropriate. Sensitivity, specificity, positive and negative predictive values and accuracy of each stone type and their confidence interval (95% CI) were also calculated. A probability value (p-value) less than 0.05 was considered statistically significant. All statistical calculations were done using SPSS (Statistical Package for the Social Science) 21version statistical program for Microsoft Windows.

OBSERVATION AND RESULTS

1) Demographic Data:

A total of 53 patients were studied. The age range of patients was 13-79 yrs (Figure 1) including 32 males and 21females.

The majority of patients are of age between 41-60 years with 54.7% patients, followed by 61-70 years with 17% of patients, 31-40 years with 15.1%, 21-30 and >70 with 5.7% each and <=20 with least no of patients i.e. 1.9%.

The majority of patients were males with 60.4% patients and 39.6% patients were females. (Figure 2)

Table 2: Distribution of cases with nephrolithiasis according to Age

Age	Frequency	Percent
<=20	1	1.9
21-30	3	5.7
31-40	8	15.1
41-50	14	26.4
51-60	15	28.3
61-70	9	17.0
>70	3	5.7
Total	53	100.0

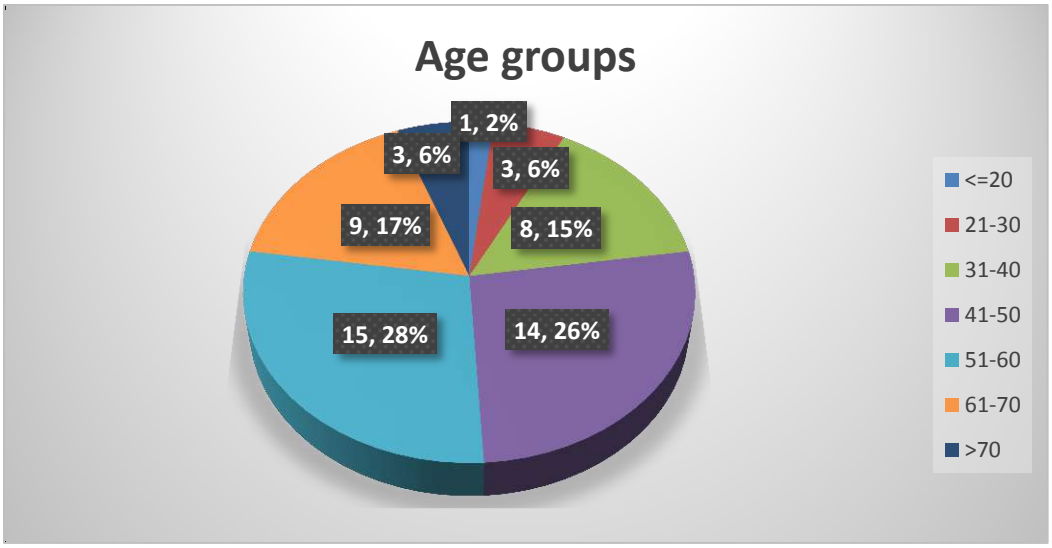

Figure 1: Pie chart depicting the age distribution of the patients.

Table 3: Distribution of cases with nephrolithiasis according to gender

sex	Frequency	Percent
Female	21	39.6
Male	32	60.4
Total	53	100.0

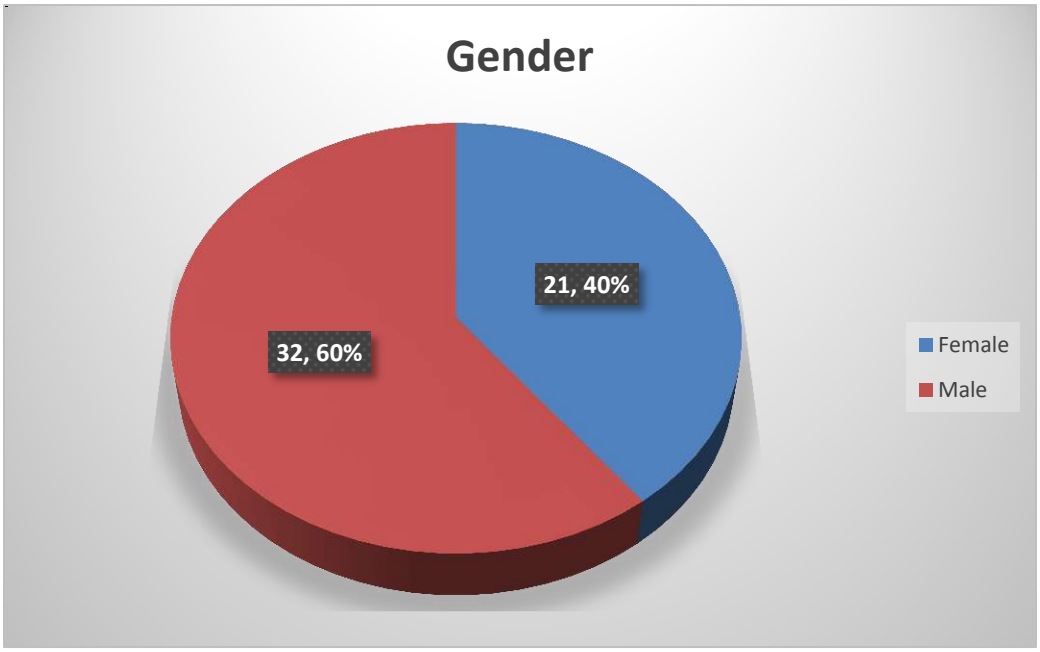

Figure 2: Pie chart depicting the distribution of cases with nephrolithiasis according to gender

2) Number and laterality of stones:

Of a total of 53 patients, 31 patients had single stones while 22 had multiple stones , of these multiple stones 19 patients had two stones while 3 had three stones(Figure 3). Total 78 stones were assessed.

42 stones (53.8%) have been reported on right side while 36 stones (46.2%) have been seen on the left side (Figure 4).

Table 4: Distribution of cases with nephrolithiasis according to no. of stones

No. of stone	Frequency	Percent
single	31	58.5
multiple	22	41.5
Total	53	100.0

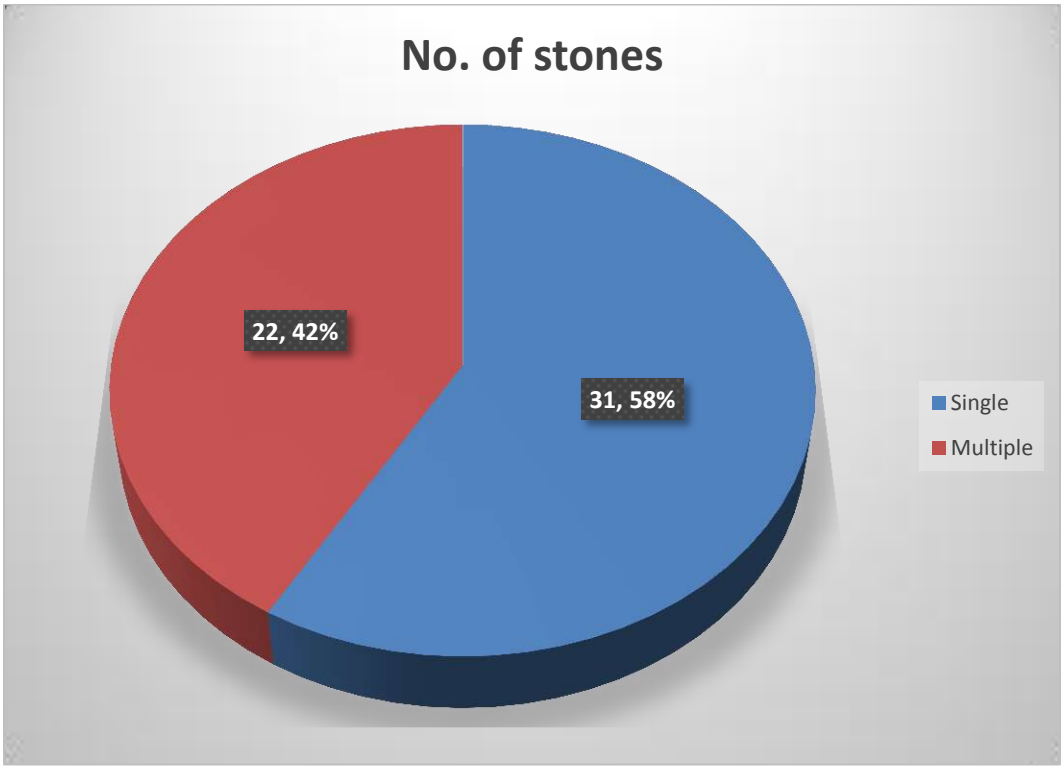

Figure 3: Pie chart depicting the distribution of cases with nephrolithiasis according to no. of stones

Table 5: Distribution of stones with nephrolithiasis according to laterality

Laterality	Frequency	Percent
Left	36	46.2
Right	42	53.8
Total	78	100

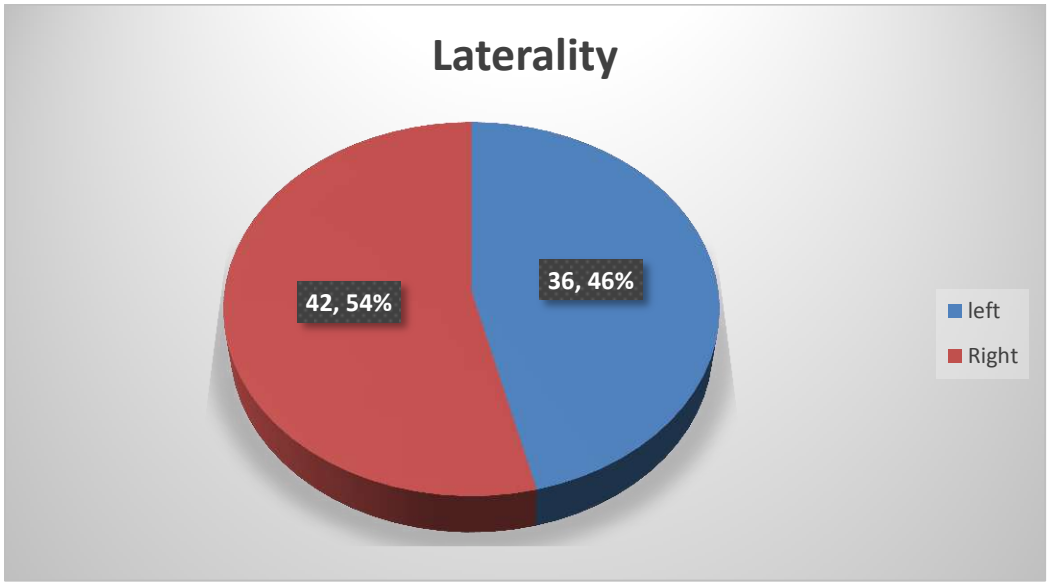

Figure 4: Pie chart depicting the distribution of cases with nephrolithiasis according to laterality

3) Location and size of calculus

The majority of the stones were located in the lower calyx (26.9% of stones) followed by the renal pelvis (24.4% of stones), PUJ with 14.1% of stones, middle calyx with 12.8% of stones, upper calyx and ureter with 9% stones each and least were staghorn calculus(3.8 %). (Figure 5)

SIZE: The majority of stones were of size between 5-15mm with 67.9% stones followed by 16-20 mm with 15.4% stones, > 20 mm stones with 9% stones and <=5mm with 7.7% stones.(Figure 6)

Table 6: Distribution of stones with nephrolithiasis according to location

Location	Frequency	Percent
Lower Calyx	21	26.9
Middle calyx	10	12.8
PUJ	11	14.1
Renal Pelvis	19	24.4
Staghorn calculus	3	3.8
Upper Calyx	7	9
Ureter	7	9
Total	78	100

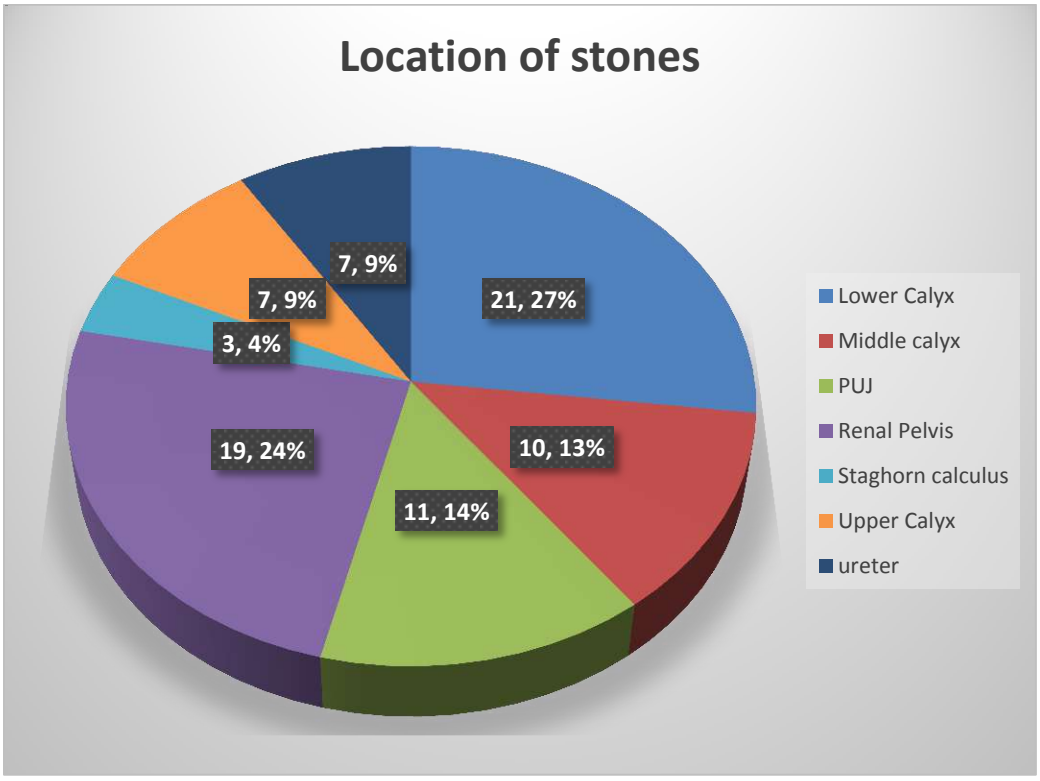

Figure 5: Pie chart depicting the distribution of stones according to location

Table 7: Distribution of stones with nephrolithiasis according to size

Stone size(mm)	Frequency	Percent
<=5mm	6	7.7
5-15 mm	53	67.9
16-20mm	12	15.4
>20mm	7	9
Total	78	100

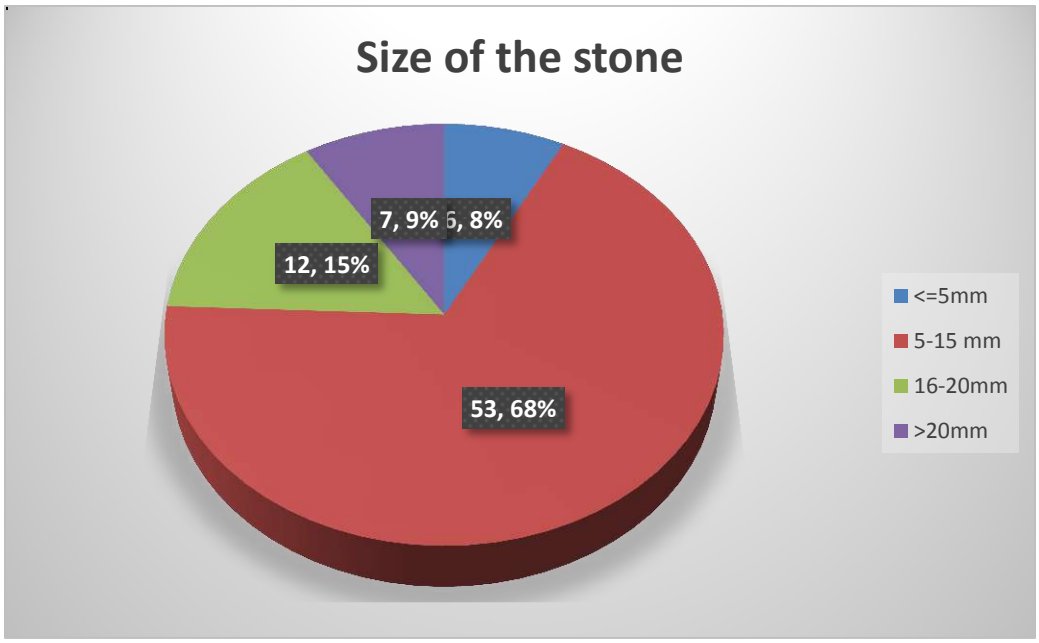

Figure 6: Pie chart depicting the distribution of stones according to Size

4) Stone diagnosis by DECT and by Lab Analysis:

Dual CT diagnosed calcium oxalate type in 37(47.4%) of stones followed by calcium hydroxyapatite in35 (44.9%) of stones and uric acid in 6 (7.7%) of stones. (Figure 7)

As per lab diagnosis, calcium oxalate type was seen in 48 (61.5%) of stones, followed by calcium hydroxyapatite in 17 (21.8%) of stones, uric acid in 7 (9%) and mixed stones in 6(7.7%) of stones. (Figure 8)

Table 8: Distribution of type of stone type according to diagnosis by DECT

DECT	Frequency	Percent
Calcium hydroxyapatite	35	44.9
Calcium oxalate	37	47.4
Uric acid	6	7.7
Total	78	100

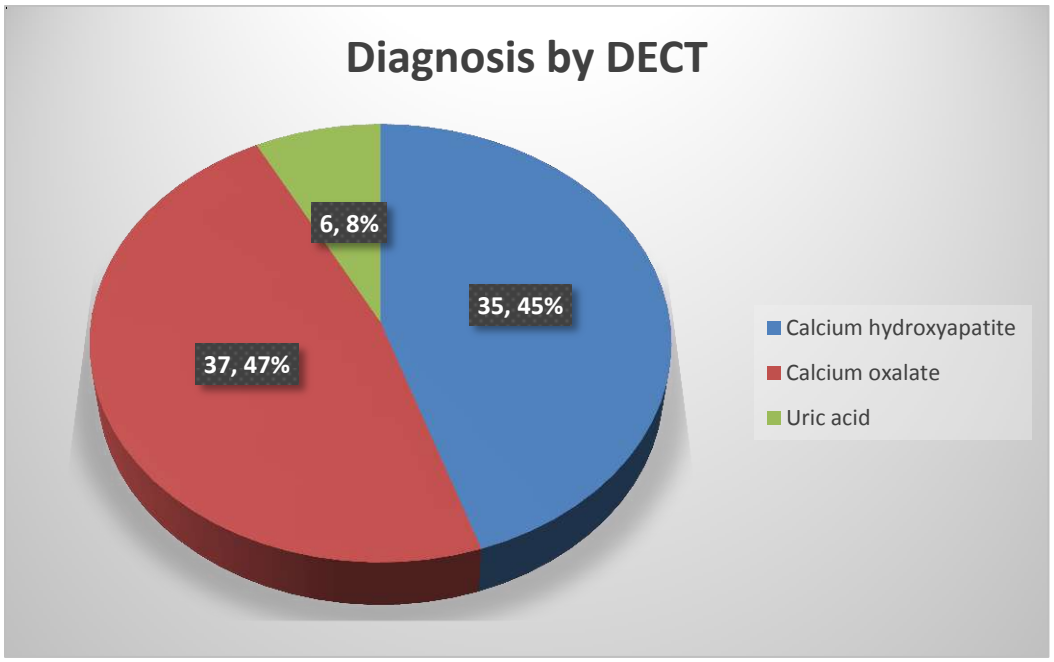

Figure 7: Pie chart depicting the type of stone according to diagnosis by DECT

Table 9: Distribution of type of stone according to lab analysis

Lab Analysis	Frequency	Percent
Calcium hydroxyapatite	17	21.8
Calcium oxalate	48	61.5
Uric acid	7	9
Mixed stones	6	7.7
Total	78	100

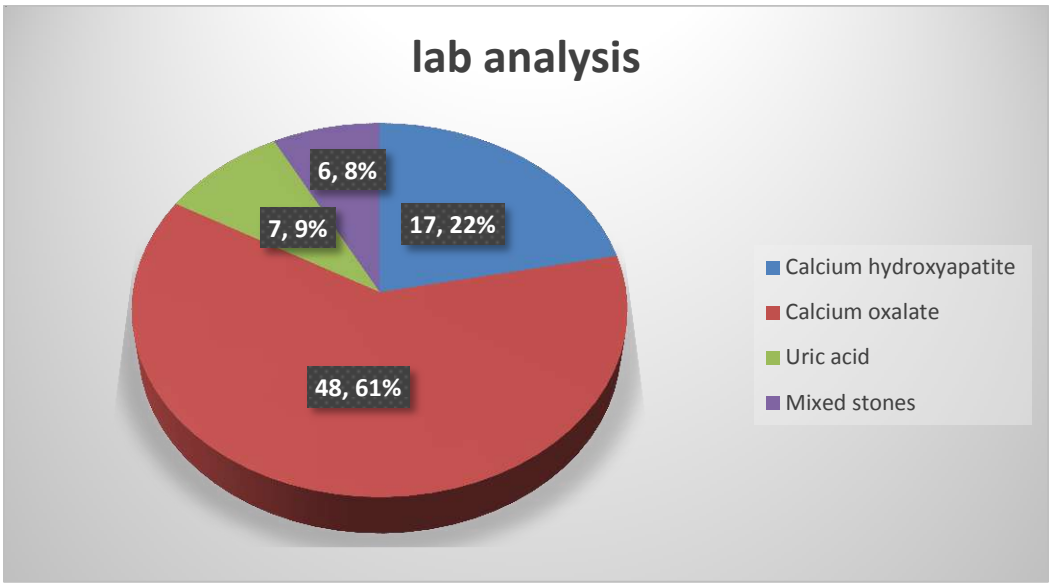

Figure 8: Pie chart depicting the type of stone according to lab analysis

5) Attenuation Ratio with respect to stone diagnosed on lab analysis

The attenuation ratio was higher in calcium hydroxyapatite (1.69±.27) and mixed stone (1.64±.33) followed by calcium oxalate with an attenuation ratio of 1.53±0.10 mm and the least AR was observed in uric acid stones with 1.02±0.03 mm. This association was highly significant.

Table 10: Mean value of the attenuation ratio with respect to the type of stone diagnosed by the lab analysis

Stone type by Lab Diagnosis		N	Mean AR	Std. Deviation	f-value	p-value
	Calcium oxalate	48	1.53	0.103	25.264	<0.001
	Uric acid	7	1.02	0.037		
	Mixed stones	6	1.64	0.331		
	Total	78	1.53	0.242		

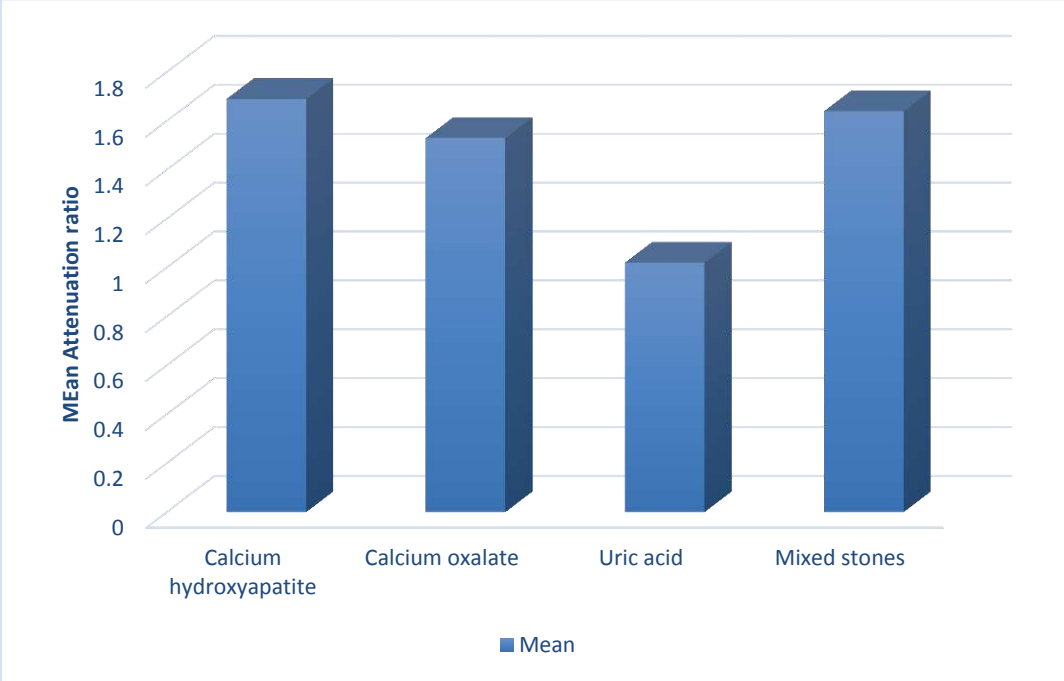

Figure 9: Mean value of the attenuation ratio with respect to the type of stone diagnosed by the lab analysis

6) Comparison of type of stone diagnosed with DECT and lab analysis and Predictive values for types of stones analysed.

a) Calcium hydroxyapatite

TABLE 11: Comparison of stones diagnosed as calcium hydroxyapaptite on DECT with Lab analysis.

Dual CT	LAB ANALYSIS			
	Ca Hydroxyapatite	Calcium Oxalate	Uric Acid	Mixed type
35	17	15	0	3
	48%	42.9%	0.0%	8.6%

The total number of 35 stones was diagnosed as Calcium hydroxyapatite by DECT. On Lab analysis 17 (48.6%) of these were also identified as Calcium hydroxyapatite, 15 (42.9%) were identified as calcium oxalate, and 3(8.6%) as mixed stones, with none identified as uric acid stones.

TABLE 12: Predictive value of calcium hydoxyapatite stone.

Statistic	Value	95% CI
Sensitivity	48.57%	31.38% to 66.01%
Specificity	100.00%	91.78% to 100.00%
Positive Predictive Value (*)	100.00%	80.49% to 100.00%
Negative Predictive Value (*)	70.49%	63.39% to 76.72%
Accuracy (*)	76.92%	66.00% to 85.71%

The sensitivity of DECT for diagnosing calcium hydroxyapatite stone was 48.57% while specificity was 100%, PPV was 100% and NPV was 70.49%. The overall accuracy was 76.92%.

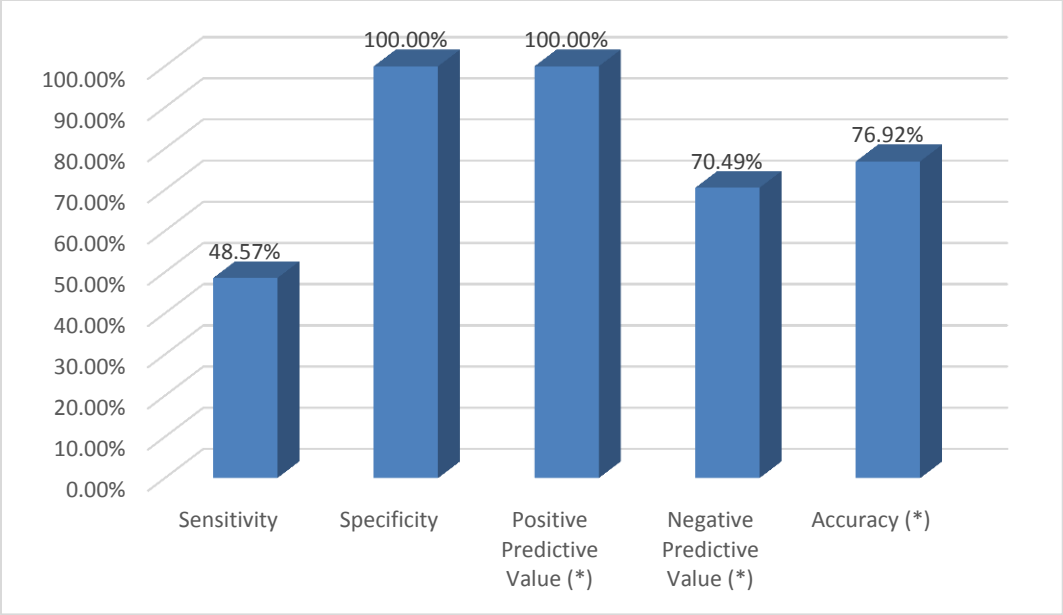

Figure 10: Predictive value of calcium hydoxyapatite stone.

b) Calcium Oxalate

TABLE 13: Comparison of stones diagnosed as calcium oxalate on DECT with Lab analysis

DECT	Lab Analysis			
	Ca Oxalate	Ca Hydroxyapatite	Uric Acid	Mixed type
37	33	0	1	3
	89.2%	0.0%	2.7 %	8.1%

Total number of 37 stones were diagnosed as calcium oxalate by DECT. On lab analysis, 33 stones (89.2%) matched the diagnosis of calcium oxalate, 1 stone (2.7%) was identified as uric acid, and 3 stones (8.1%) as mixed stones, with none identified as Calcium hydroxyapatite.

TABLE 14: Predictive value of calcium oxalate stones.

Statistic	Value	95% CI
Sensitivity	68.75%	53.75% to 81.34%
Specificity	86.67%	69.28% to 96.24%
Positive Predictive Value (*)	89.19%	76.46% to 95.44%
Negative Predictive Value (*)	63.41%	52.69% to 72.96%
Accuracy (*)	75.64%	64.60% to 84.65%

The sensitivity of DECT for diagnosing calcium oxalate stone was 68.75% while specificity was 86.67%, PPV was 89.19% and NPV was 63.41%. The overall accuracy was 75.64%.

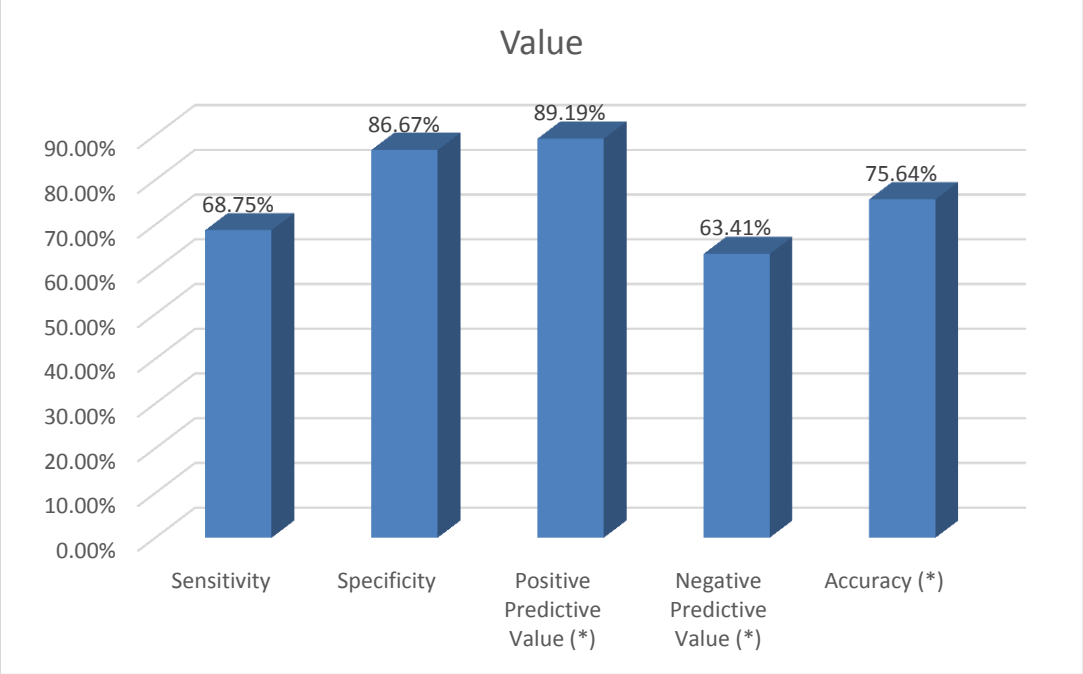

Figure 11: Predictive value of calcium oxalate stones.

c) Uric acid stone

TABLE 15: Comparison of stones diagnosed as Uric acid on DECT with Lab analysis

DECT	Lab Analysis			
	Uric acid	Calcium oxalate	Calcium Hydroxyapatite	Mixed type
6	7	0	0	0
	100%	0%	0.0%	0.0%

Total 6 stones identified as uric acid by DECT were 100% matched with the lab diagnosis of uric acid. One calculi diagnosed as Ca oxalate on DECT turned out to be uric acid type on lab analysis.

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TABLE 16: Predictive value of uric acid stone

Statistic	Value	95% CI
Sensitivity	100.00%	54.07% to 100.00%
Specificity	98.61%	92.50% to 99.96%
Positive Predictive Value (*)	85.71%	46.14% to 97.68%
Negative Predictive Value (*)	100.00%	94.94% to 100.00%
Accuracy (*)	98.72%	93.06% to 99.97%

(*) These values are dependent on disease prevalence.

The sensitivity of DECT for diagnosing uric acid stone was 100% while specificity was 98.61%, PPV was 85.71% and NPV was 100%. The overall accuracy was 98.72%.

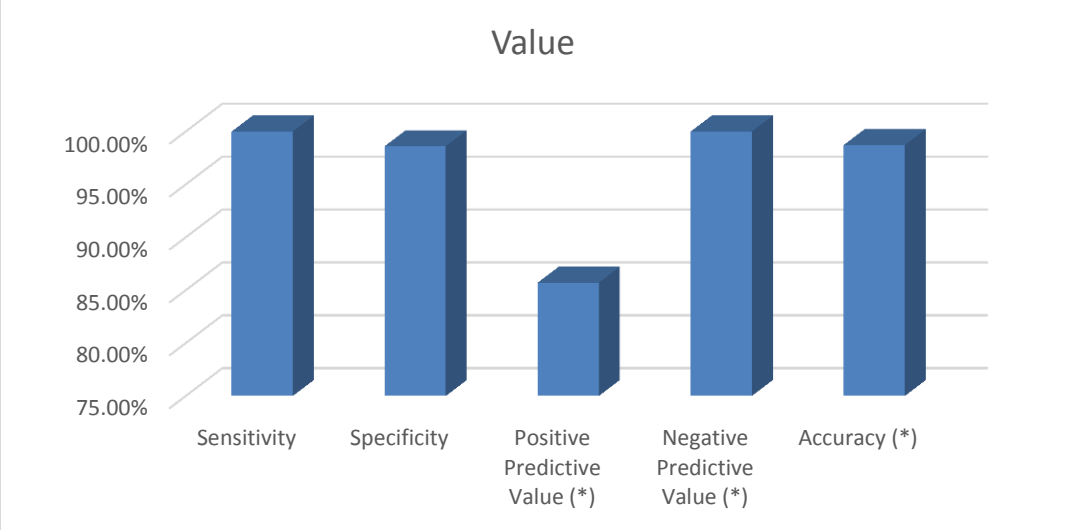


Figure 12: Predictive value of uric acid stone

d) Ca and non-calcium stones.

The calcium containg stones identified were Calcium oxalalte, Calcium Hydroxyapatite stones and non calcium containg stones identified were Uric acid stones and mixed stone type.

TABLE 17: Predictive value in detecting Calcium vs Non Calcium stones.

Statistic	Value	95% CI
Sensitivity	90.28%	80.99% to 96.00%
Specificity	100.00%	54.07% to 100.00%
Positive Predictive Value (*)	100.00%	94.48% to 100.00%
Negative Predictive Value (*)	46.15%	29.78% to 63.41%
Accuracy (*)	91.03%	82.38% to 96.32%

(*) These values are dependent on disease prevalence.

The sensitivity of DECT for diagnosing calcium stones with respect to non calcium stone was 90.28% while specificity was 100%, PPV was 100% and NPV was 46.15%. The overall accuracy was 91.03%.

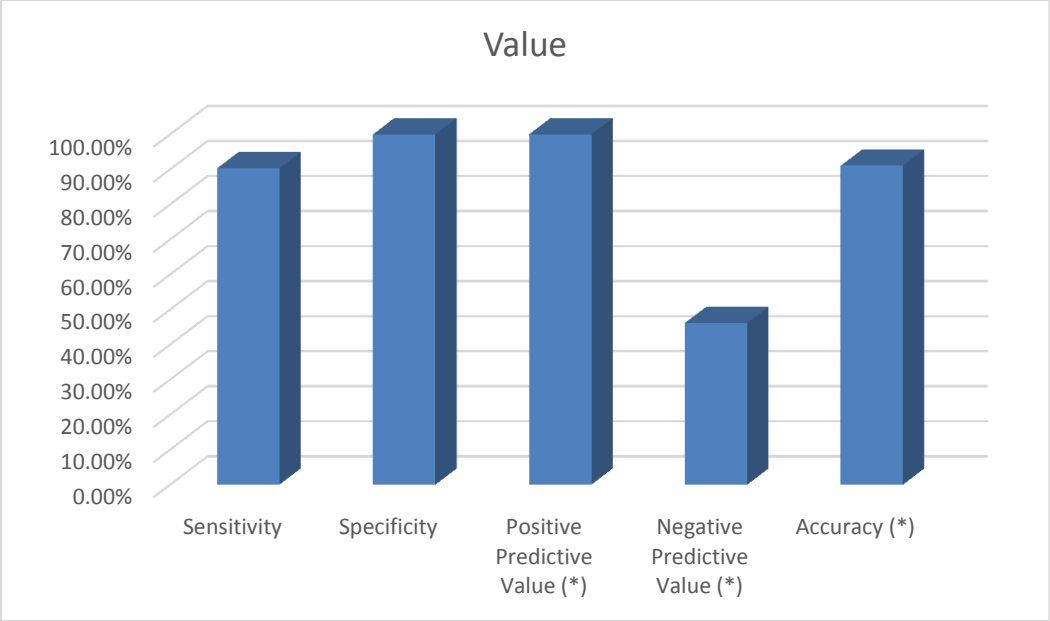
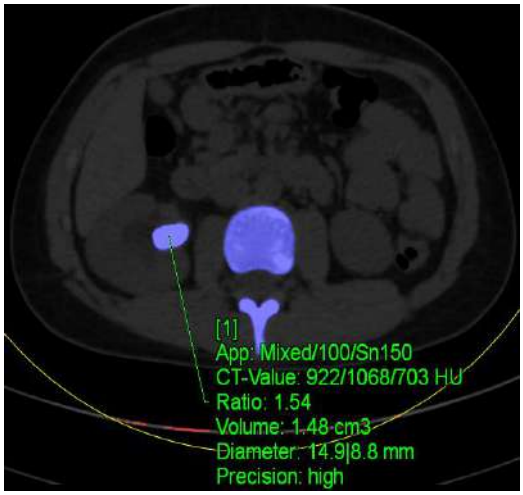
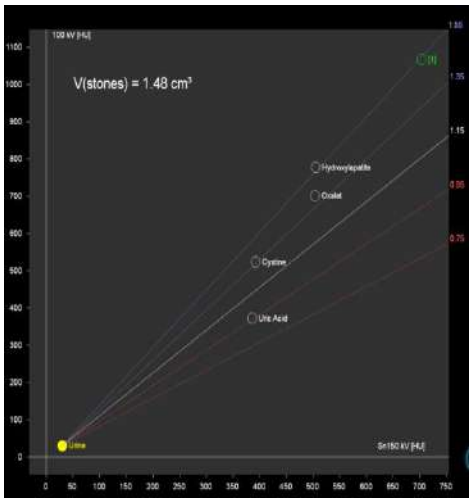


Figure 13: Predictive value in detecting Calcium vs Non Calcium stones.

CASE 1: 13 yr old male presented with right flank pain.

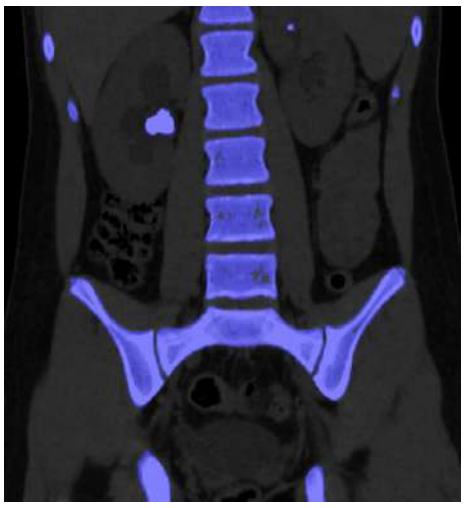


(A)



(B)

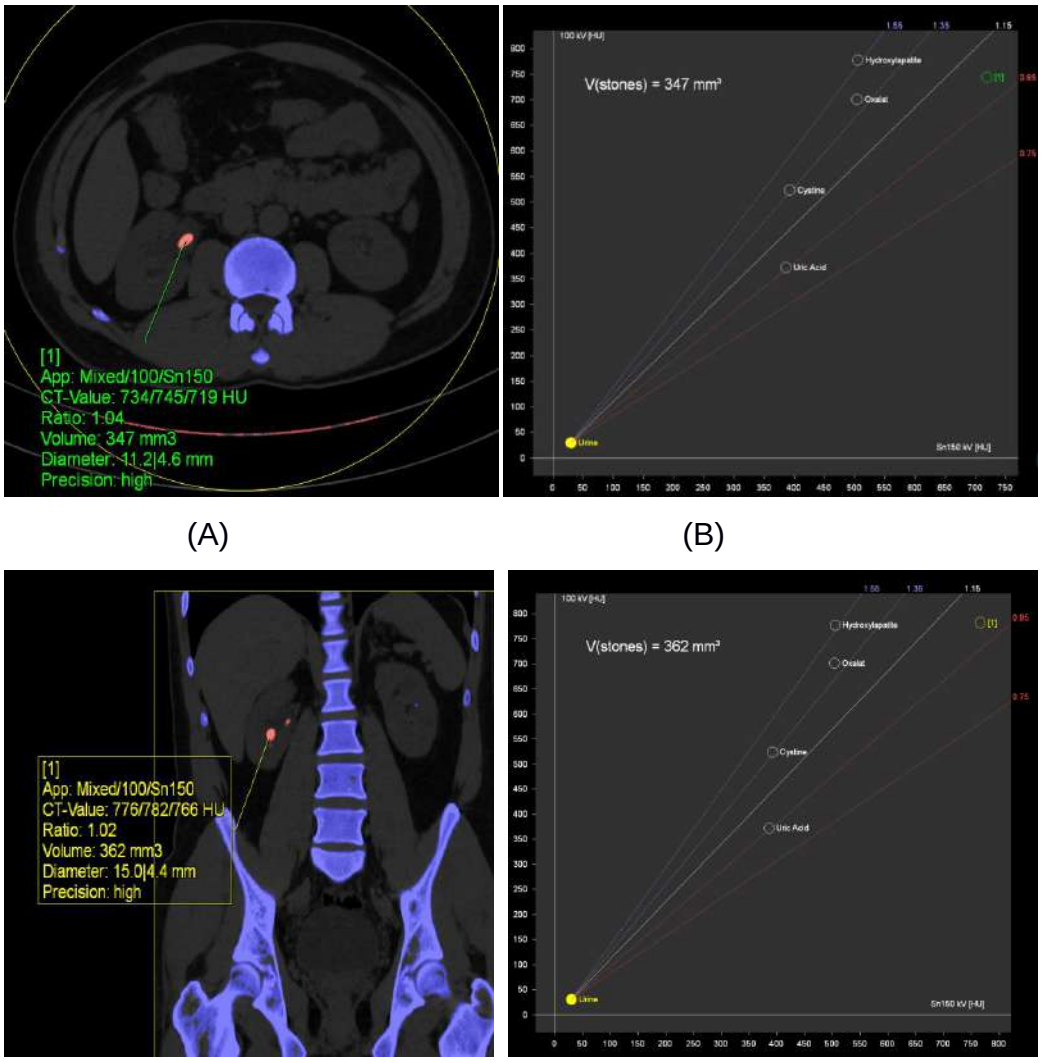
(C)



(D)

Fig 14: DECT reveals a partial staghorn calculus conforming to shape of pelvis on right side measuring 16 x 11.5 mm, with an attenuation ratio of 1.54 s/o calcium oxalate stone type (A)(C). The stone was coloured blue (D). (b)The graph shows attenuation ratio (1) lying in the range of calcium oxalate stones (B). Patient underwent PCNL and on lab analysis it came out to be composed of calcium oxalate as well.

CASE 2: 32 yrs old male patient presented with right colicky pain.



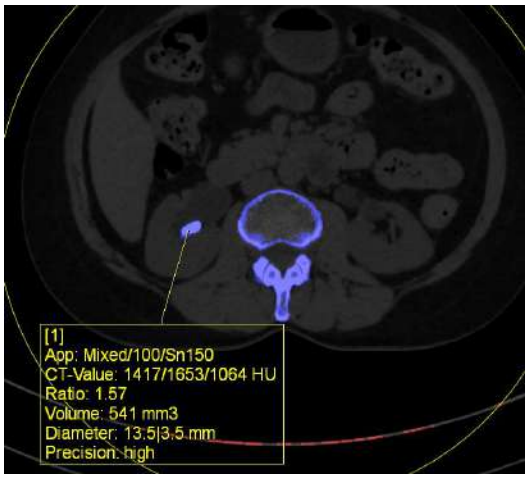
(A) (B)

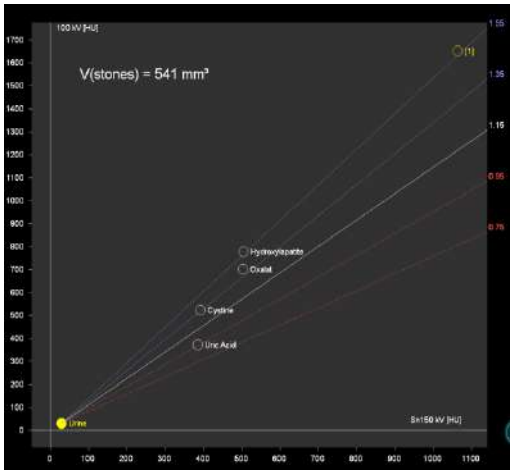
(C) (D)

Fig 15. DECT reveals two calculi in right kidney with a 11 mm calculus in right renal pelvis with attenuation ratio of 1.04 coloured red (A). Another calculus measuring 10 x 9 mm in right lower calyx with attenuation ratio of 1.02, also coloured red (C). Both stones came under range of uric acid type on graph (B) (D).

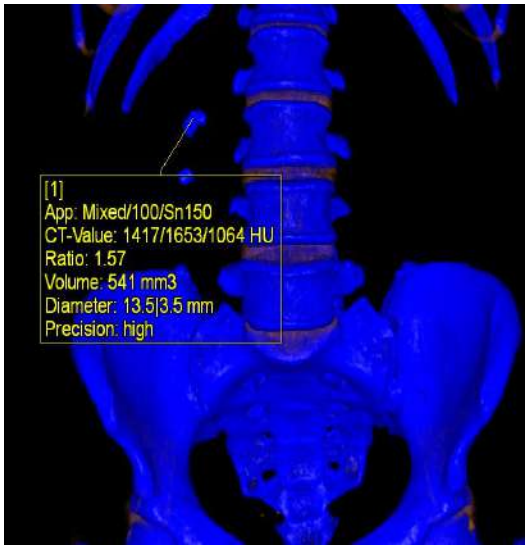
Patient underwent PCNL and on lab analysis of stones these turned out to be of uric acid type as well.

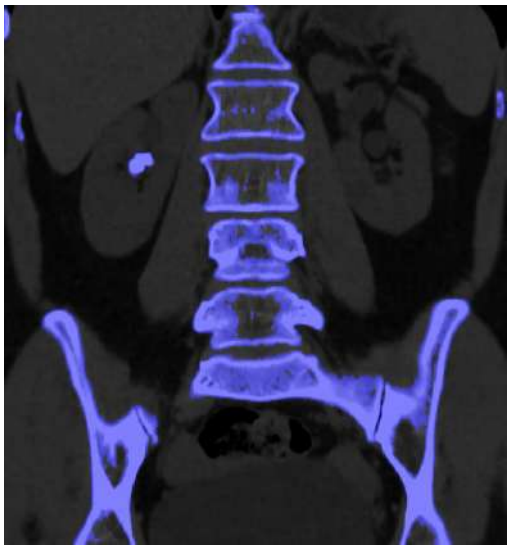
CASE 3: 45 yrs old female patient presented with pain right flank region.





(A) **(B)**



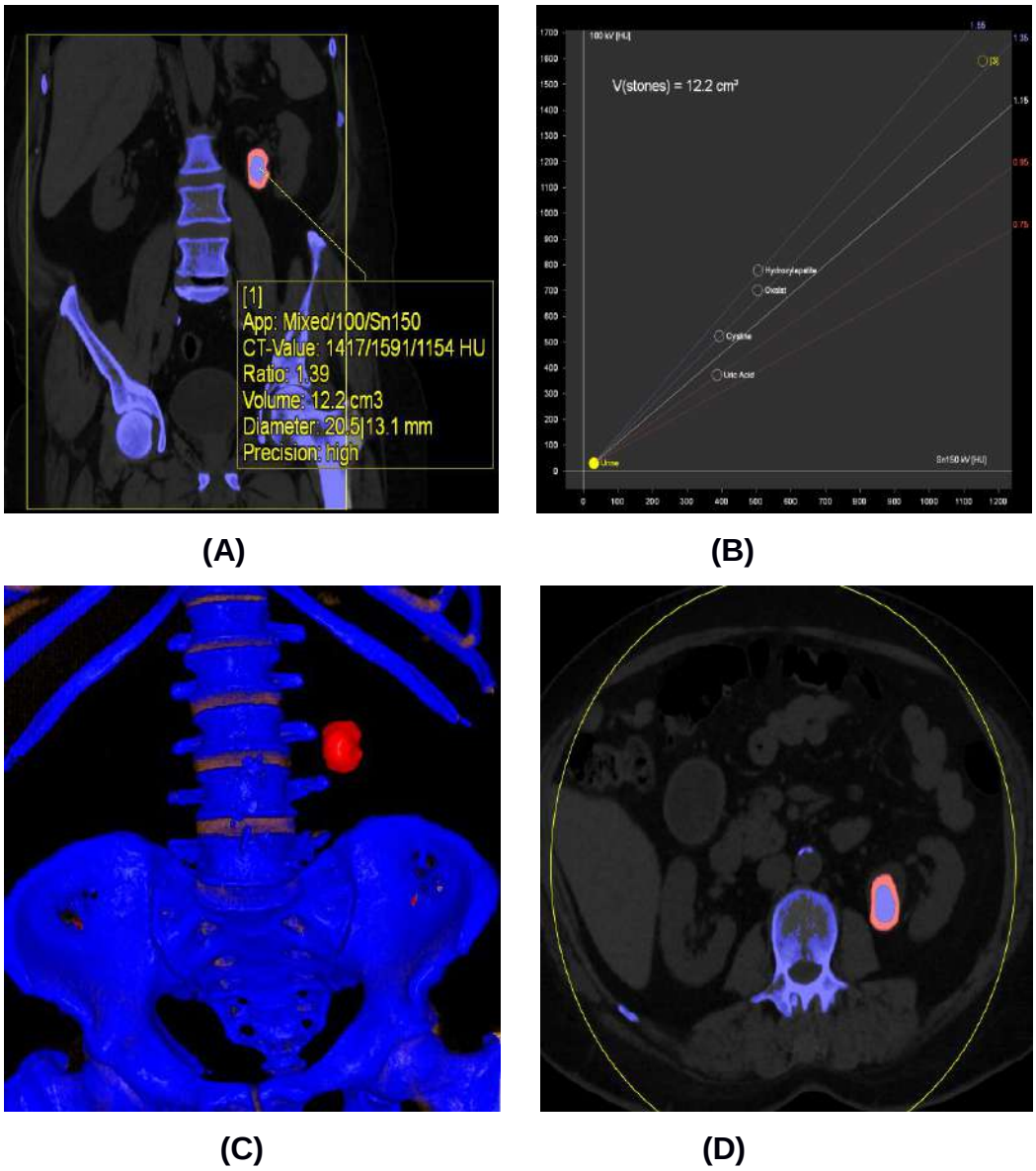


(C) **(D)**

Fig 16: DECT revealed a calculus measuring 16 mm in the right middle calyx with attenuation ratio of 1.57, coloured blue (A)(C).

On graph it comes under range of calcium hydroxyapatite type (B). Patient underwent PCNL and the calculus came out to be of calcium hydroxyapatite type as well on lab analysis.

CASE 4: 64 yrs old male presented with pain abdomen



(A) **(B)**

(C) **(D)**

Fig 17: DECT reveals a calculus in left pelviureteric junction measuring 32 x 30 mm with attenuation ratio of 1.39 (A). It comes under the range of calcium oxalate type as shown on graph (B). Patient underwent PCNL and on lab analysis of stone it came out to be mixed composition stone.

CASE 5: 39 yrs old female presented with left colicky pain and mild left hydronephrosis on USG.

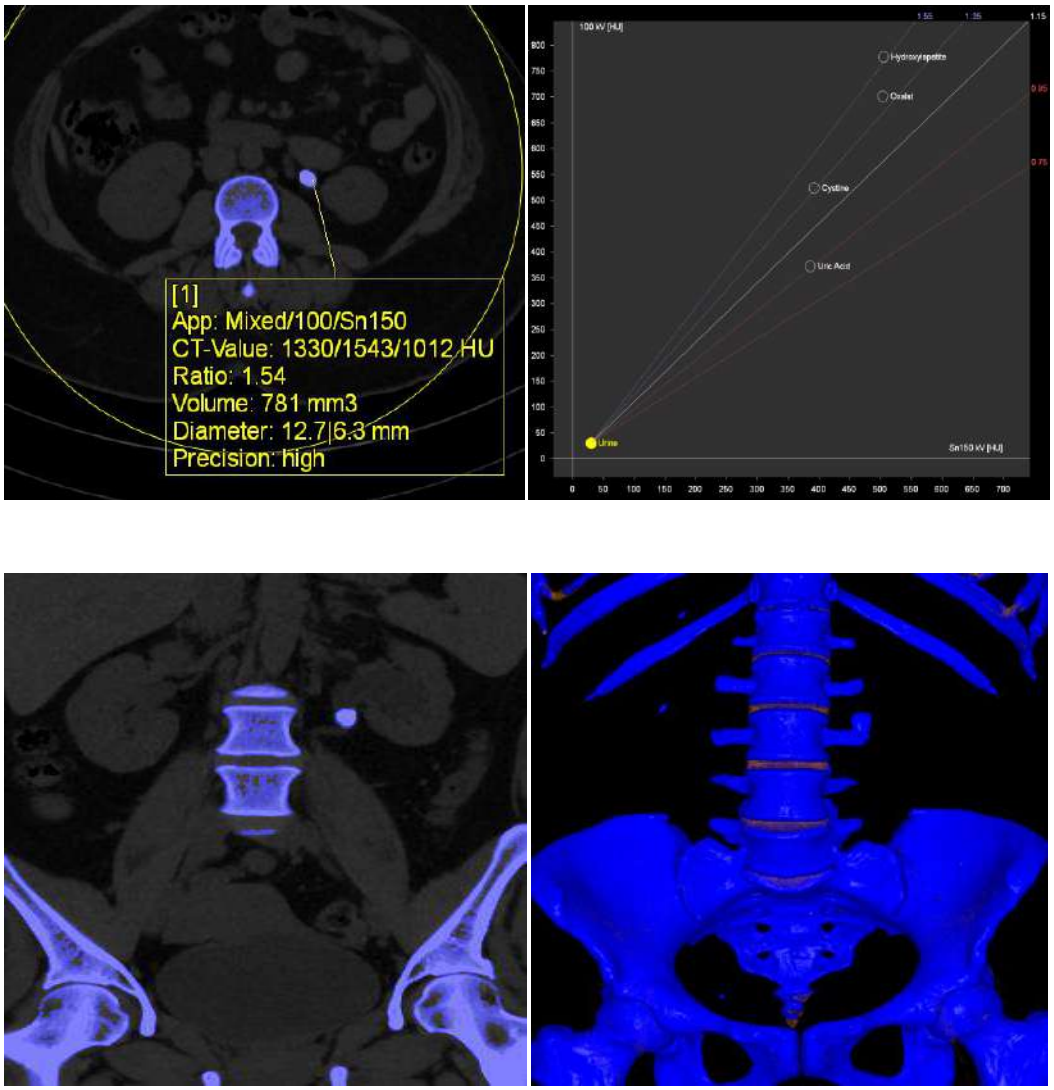


Fig 18: DECT reveals a calculus measuring 15 x 10 mm in left PUJ with attenuation ratio of 1.54 suggestive of calcium oxalate stone type. On Lab analysis it turned out to be composed of same type.

DISCUSSION

The prevalence of nephrolithiasis has been increasing worldwide. The size, number, location, and composition of stones all contribute to the overall burden and influence treatment decisions.[58] Computed tomography (CT) is highly sensitive in detecting renal stones, making it an invaluable tool in assessing stone burden. Dual Energy Computed Tomography (DECT) has emerged as a valuable tool in the comprehensive evaluation and management of urolithiasis by providing accurate stone characterization, reducing radiation exposure, detecting associated urinary tract abnormalities, assessing treatment response.

The present study was conducted in the Department of Radiodiagnosis at Dayanand Medical College and Hospital, Ludhiana. A total of 53 patients scheduled to undergo surgical extraction of renal stones were included in the study. The study was conducted to determine the role of DECT in the characterisation and management of renal stones. In this study after the characterisation of the calculus via DECT, surgical extraction was done. The chemical composition of the stones was determined by laboratory analysis and was compared with the findings of DECT.

In our study, the majority of patients diagnosed with urolithiasis were aged between 41-60 years, comprising 54.7% of the total, followed by those aged 61-70 years at 17%, and 31-40 years at 15.1%. Patients aged 21-30 years and over 70 years each accounted for 5.7%, while those aged ≤20 years constituted the smallest group at 1.9%. The average age of patients was 50.44±13.16 years.

In 2020, Panchal et al.[58] conducted a study involving 100 patients with renal stones, reporting that the largest proportion (48%) fell within the 41-60 years age group, followed by 21-40 years (42%), with 8% of patients aged over 61 years. Patients under 20 years old comprised only 2% of the total. Patel PB et al. [59] noted in their study that the highest incidence of

kidney stones occurred in individuals aged 20-40 years (51%). Similarly, Gillen et al.[60] reported a mean patient age of 54.1±0.7 years. These findings are consistent with those of the present study.

The majority of patients diagnosed with urolithiasis in our study were males with 60.4% of patients and 39.6% of patients being females.

Patel PB et al [59] in their study realized a very high percentage of males with renal calculi (89%) compared to females (11%). Maharaul et al. [61] in their study conducted in 2022 on 150 patients with nephrolithiasis found a male preponderance with 69.3% of the total patients being males. Both above studies are in confirmation with the present study. However, a study by Panchal et al [58] showed contrasting results with the majority of patients being females (82%).

In our study, we conducted a comparison between lab analysis and DECT findings, revealing that DECT identified calcium oxalate in 47.4% of stones, calcium hydroxyapatite in 44.9%, and uric acid in 7.7%. The agreement between DECT and lab analysis, as measured by a kappa value of 0.533, indicated moderate similarity, which was statistically significant.

The sensitivity of DECT for diagnosing calcium hydroxyapatite stone was 48.57% while specificity was 100%, PPV was 100% and NPV was 70.49%. The overall accuracy was 76.92%. The sensitivity of DECT for diagnosing calcium oxalate stone was 68.75% while specificity was 86.67%, PPV was 89.19% and NPV was 63.41%. The overall accuracy was 75.64%. The sensitivity of DECT for diagnosing uric acid (UA) stone was 100% while specificity was 98.61%, PPV was 85.71% and NPV was 100%. The overall accuracy was 98.72%.

Our observations are in concordance with the study conducted by Bhawani et al.[62] Bhawani et al found agreement between DECT and chemical analysis in differentiating uric acid calculi and non-uric acid calculi. Also in their study, DECT demonstrates comparable sensitivity and accuracy to chemical analysis in differentiating uric acid calculi from non-uric acid calculi ($p<0.001$ and kappa value = 1.0). Moreover, a noteworthy agreement exists between DECT and chemical analyses in discerning calcium oxalate calculi from non-calcium oxalate calculi ($p<0.001$ and kappa value = 0.883). Bhawani et al [62] found a sensitivity and specificity of 97.5% and 90.9%, respectively, for differentiating calcium oxalate calculi from non-calcium oxalate calculi, with an overall accuracy of 96%. Additionally, the sensitivity and specificity for discriminating uric acid calculi from non-uric acid calculi were both 100%.

Our findings align with those of Zeng et al. (2016) [45], who conducted a meta-analysis evaluating the capability of DECT to differentiate between uric acid and calcified stones. They reported a pooled sensitivity of 95% and specificity of 98% for distinguishing uric acid stones from non-uric acid stones.

Our study's findings, indicating that DECT did not effectively distinguish between certain subtypes of calcium stones and mixed stones, are consistent with the conclusions drawn by Mohammed M Dawoud.[49] According to their research, while DECT successfully differentiated uric acid from calcium stones, it faced difficulties in distinguishing between calcium oxalate and calcium phosphate in some cases, as well as identifying stones with mixed compositions.

Our analysis are also in parallel with study done by Manglaviti et al. [63], and Ilyas et al.[64] According to Manglavati there was "substantial agreement between dual-energy CT and crystallography for pure stones

(Cohen κ = 0.684)" in their study, however "DECT" was unable to detect stones with a mixture of elements. They also proved there was no relationship between "stone diameter" and "stone CT density" and stone composition.

In a study conducted by Ilyas et al, it was observed that DECT demonstrated a sensitivity and specificity of 100% in distinguishing "UA stones" from "non-UA stones". Moreover, it exhibited a sensitivity of 97.8% and specificity of 92.3% in differentiating "calcium oxalate" from "non-calcium oxalate" calculi. The "DE ratio" for "UA stones" was found to range between 0.98 and 1.13. These results align with the outcomes of the present study.

Our findings contrast with those of Erdogan et al.[48] and Avinav Bharati.[54] In the study by Erdogen et al. DECT demonstrated a high sensitivity and specificity of 100% for distinguishing between uric acid and cystine stones. Additionally, it achieved a sensitivity of 83.3% and specificity of 100% for differentiating between calcium oxalate and calcium hydroxyapatite stones. In study by Avinav Bharati et al, they reported that DECT effectively distinguished between various subtypes of calcium stones, as well as uric acid, cystine, and mixed stones, achieving sensitivities of 100%, 100%, and 85.7%, respectively.

In contrast, our study observed relatively lower sensitivity and specificity in detecting calcium oxalate and calcium hydroxyapatite stones.

The discrepancy is likely attributable to the smaller sample size and demographic differences in our study compared to these studies.

In our current study attenuation ratio (AR) was higher in calcium hydroxyapatite (1.69±.27) and mixed stone (1.64±.33) followed by calcium oxalate with an attenuation ratio of 1.53±0.10 mm and the least AR was observed in uric acid stones with 1.02±0.03 mm. This association was very significant.

Bhaskarraj et al. [65] observed that the attenuation rates (AR) of pure uric acid stones were significantly lower compared to the majority of calcium stones. Similarly, Ilya M et al.[64] noted that the AR for uric acid stones were notably lower than those for most calcium stones, while the attenuation values for other types of stones ranged from 600 HU to 2800 HU, consistent with our findings.

In their study, Bhawani et al.[62] found a significant difference in the mean DE ratio between uric acid stones (1.01±0.061) and non-uric acid stones (1.42±0.162), with a p-value<0.001. Similarly, Shalini et al. [53] observed that a DE ratio below 1.1 typically indicated uric acid calculi, while a DE ratio ranging from 1.1 to 1.24 was characteristic of cystine calculi. A DE ratio above 1.24 was indicative of calcium calculi, which is in concordance with our study's findings.

In our study, calcium stones were predominant, comprising 83.3% of all stones, while non-calcium or mixed stones accounted for 16.7%. Lab diagnosis revealed that calcium oxalate was present in 61.5% of cases, calcium hydroxyapatite in 21.8%, uric acid in 9%, and mixed stones in 7.7%.

Ansari et al.[66] conducted a study in northern India involving 1050 renal stones, revealing that calcium oxalate stones constituted the majority, accounting for 93.04% of cases. Uric acid stones were found in 0.95% of cases, and mixed pattern stones made up the remaining 2.76%. Similarly, Rao et al.[67], in their research in Delhi, analyzed 51 stones and observed that 96% of them were composed of calcium oxalate. Additionally, Ahlawat et al.[68] and Sharma et al.[69] reported that calcium oxalate stones accounted for 97% and 86.1% of renal stones, respectively in their studies.

In their study, Bhawani et al.[62] found that 78% of the calculi in their study population were composed of calcium oxalate stones. Uric acid stones accounted for 12%, cystine stones for 6%, and hydroxyapatite stones for 4%. These findings align with the results of the present study.

In the present study, we observed that in a total of 53 patients, 31(58.5%) patients diagnosed with single stones while 22(41.5%) had multiple stones, of these multiple stones 19 patients had two stones while 3 had three stones. In the study conducted by Shazib et al [70] in 2020 a total of 621 patients of urolithiasis were included. They found that 63.1% of patients had single urinary tract stones which corresponds with our study findings. In the study conducted by Rajeev TP et al [71] in 2018, 85 patients were found with multiple stones out of 151 patients included in this study, single stones were found in 66 patients. This was in contrast to the present study.

In our study, 53.8% of patients presented with stones on the right side, whereas 46.2% had stones on the left side. Shajib et al.[70] reported a prevalence of 41.72% for right-sided calculi in their study. Hallawee S [72] found an equal frequency of stone occurrence on both sides. The anatomical proximity between the kidney and liver may provide a plausible explanation for the size and number of stones detected in the right kidney, as the right kidney typically sits approximately 2 cm lower than the left kidney. [64]

In our study ,the more number of stones were located in the lower calyx with 26.9% of stones followed by the renal pelvis with 24.4% of stones, PUJ with 14.1% of stones, middle calyx with 12.8% of stones, upper calyx and ureter with 9% stones each and least were staghorn calculus.

In the study by Shazib et al. [70], kidney stones were detected in 67.4% of 419 patients examined. The distribution of ureteral stone locations included the upper third in 16.6% of cases, middle third in 2.1%, lower third in 5.5%, and vesical stones in 2.6%. Stones were found in multiple locations in 5.5% of patients. The prevalence of urolithiasis varies geographically. Chand et al. [73] reported in 2013 that among 240 patients, 75.08% had renal stones, 13.62% had stones in the ureters, 9.56% had stones at the vesicoureteral junction (VUJ), and 1.74% had vesical stones, aligning with global trends observed in their study. Durgawale et al.[74] conducted a study in 2010 with 125 patients to analyze the chemical composition of stones, noting a higher incidence in the ureter followed by the bladder, urethra, and kidney. In the study by Bhawani et al[62] conducted on 50 patients with urolithiasis most of the calculi were in the renal calyceal system (40%) followed by the ureters (36%) and the renal pelvis (24%).+

The potential of DECT to achieve element decomposition has made it a highly successful tool, especially in distinguishing materials with similar beam attenuation but different atomic numbers, such as iodinated contrast material and calcium. This ability is particularly beneficial in renal stone evaluation, permitting identification of stone chemical composition and preoperative analysis to differentiate calcium-containing stones from cystine stones. [57]

The ability to identify uric acid calculi using Dual energy ratios can significantly impact patient management, enabling medical management with allopurinol and alkalinization of urine. This approach is particularly beneficial for patients with familial metabolic diseases, such as cystinuria, who can be medically managed with captopril, thereby avoiding more invasive and potentially costly treatments like ESWL or PCNL, which carry risks of complications including hemorrhage and sepsis.[57]

Urologists consider various characteristics of renal stones before advising an appropriate treatment approach, including stone size, number, location, and composition, along with renal anatomy and clinical factors. DECT facilitates better characterization of renal stones in terms of fragility, burden, and composition, aiding in predicting the success of procedures like ESWL, RIRS, or PCNL. [57]

Measurement of stone size using CT assists in predicting the rate of spontaneous excretion of renal and ureteral stones, with medical management indicated for stones less than 7 mm in size. ESWL is effective for stones less than 1.1 cm in size and with normal renal anatomy, while PCNL or ureteroscopy is preferred for larger stones or those with compositions like calcium oxalate monohydrate, brushite, or cystine. [57]

The location of the calculus within the pelvi- calyceal system is crucial for safe and appropriate puncture positioning during PCNL, with stones located in posterior calyces more amenable to removal by this method. DECT assists in analyzing stone composition, which is crucial for planning the management strategy, with uric acid stones being medically dissolved using urinary alkalinization therapy or allopurinol. [57]

Success rates of treatments like ESWL depend on stone composition, with denser calculi like calcium phosphate or cystine being resistant to fragmentation and requiring surgery. DECT can confidently differentiate between various stone compositions, but furthermore studies are needed to standardize DE ratios across different populations and settings. [57]

SUMMARY AND CONCLUSION

- Our study comprised 53 patients with the majority of individuals diagnosed with nephrolithiasis aged between 41-60 years. Among the patients, males constituted the majority at 60.4 %.
- Dual CT diagnosed calcium oxalate in 47.4% of stones, followed by calcium hydroxyapatite in 44.9% and uric acid in 7.7%.
- Lab analysis showed calcium oxalate in 61.5% of stones, followed by calcium hydroxyapatite in 21.8%, uric acid in 9%, and mixed stones in 7.7%.
- The sensitivity and specitivity of Dual CT in detecting calcium oxalate stones is 68.7 % and 86.6 %, in calcium hydroxyapatite is 48.5 % and 100%, in uric acid stone is 100 % and 98.6 % respectively. The sensitivity of dual CT for diagnosing calcium stones with respect to non calcium stone was 90.28% while specificity was 100%.
- The attenuation ratio was higher in calcium hydroxyapatite and mixed stones, followed by calcium oxalate and then uric acid. This association was highly significant.

- 53.8% of patients with nephrolithiasis have stones on the right side, while 46.2% have stones on the left side.
- The majority of stones in patients with nephrolithiasis are located in the lower calyx (26.9%) and renal pelvis (24.4%).
- The majority of stones in patients with nephrolithiasis are between 5-15mm in size (67.9%).
- Calcium hydroxyapatite was more common in females, while calcium oxalate, uric acid, and mixed stones were significantly more common in males.
- No significant association was found between the type of stone and location or laterality.
- No significant association was found between the type of stone and size.

Conclusion

Dual-energy CT (DECT) presents a valuable capability to differentiate calculi based on their composition, aiding urologists in guiding treatment decisions effectively. It has high sensitivity of 90 % and specificity of 100% in detecting calcium VS Non calcium stones with accuracy of 91%.

By identifying the composition of stones, DECT assists in selecting the most appropriate treatment modality and evaluating the effectiveness of energy sources used for lithotripsy. This enables clinicians to optimize patient management while minimizing the costs and morbidity associated with additional procedures.

Nevertheless, while DECT shows promise in distinguishing single-component stones, its efficacy in differentiating mixed stones and calcium subtypes stones, requires further exploration and validation. Understanding how DECT performs in characterizing mixed stones will be crucial for its broader clinical utility in accurately guiding treatment strategies for patients with complex stone compositions. Furthermore research in this area is essential to unlock the full potential of DECT in the management of urolithiasis.

BIBLIOGRAPHY

1. López M, Hoppe B. History, epidemiology and regional diversities of urolithiasis. Pediatr Nephrol. 2010;25:49-59.
2. Johnson CM, Wilson DM, O'Fallon WM, Malek RS, Kurland LT. Renal stone epidemiology: a 25-year study in Rochester, Minnesota. Kidney Int. 1979;16:624-31.
3. Stamatelou KK, Francis ME, Jones CA, Nyberg LM, Curhan GC. Time trends in reported prevalence of kidney stones in the United States: 1976-1994. Kidney Int. 2003;63:1817-23.
4. Pak CY. Kidney stones. Lancet. 1998;351:1797-801.
5. Cheng PM, Moin P, Dunn MD, Boswell WD, Duddalwar VA. What the radiologist needs to know about urolithiasis: part 1--pathogenesis, types, assessment, and variant anatomy. AJR Am J Roentgenol. 2012;198:540-7.
6. Park S, Pearle MS. Pathophysiology and management of calcium stones. *Urol Clin North Am* 2007; 34:323–34.
7. Finlayson B. Physicochemical aspects of urolithiasis. Kidney Int. 1978;13:344-60.
8. Evan AP. Physiopathology and etiology of stone formation in the kidney and the urinary tract. Pediatr Nephrol. 2010;25:831-41.
9. Miller NL, Evan AP, Lingeman JE. Pathogenesis of renal calculi. Urol Clin North Am. 2007;34:295-313.
10. Aggarwal KP, Narula S, Kakkar M, Tandon C. Nephrolithiasis: molecular mechanism of renal stone formation and the critical role played by modulators. Biomed Res Int. 2013;2013:292953.
11. Ryall RL. The scientific basis of calcium oxalate urolithiasis. Predilection and precipitation, promotion and proscription. World J Urol. 1993;11:59-65.
12. Ackermann D, Baumann JM, Futterlieb A, Zingg EJ. Influence of calcium content in mineral water on chemistry and crystallization conditions in urine of calcium stone formers. Eur Urol. 1988;14:305-8.
13. Curhan G. Imaging in the emergency department for suspected nephrolithiasis. N Engl J Med. 2014;371:1154-5.

14. Mutgi A, Williams JW, Nettleman M. Renal colic. Utility of the plain abdominal roentgenogram. Arch Intern Med. 1991;151:1589-92.
15. Reddy S. State of the art trends in imaging renal of colic. Emerg Radiol. 2008;15:217-25.
16. Dunnick RN, Sandler CM, Newhouse JH, Amis ES Jr. Nephrocalcinosis and nephrolithiasis. In: Dunnick RN, Sandler CM, Newhouse JH, Amis ES Jr, editors. Textbook of Uroradiology. Philadelphia, PA: Lippincott Williams & Wilkins; 2001:178-94.
17. Rubens DJ, Bhatt S, Nedelka S, Cullinan J. Doppler artifacts and pitfalls. Radiol Clin North Am. 2006;44:805-35.
18. Kamaya A, Tuthill T, Rubin JM. Twinkling artifact on color Doppler sonography: dependence on machine parameters and underlying cause. AJR Am J Roentgenol. 2003;180:215-22.
19. Chelfouh N, Grenier N, Higueret D, Trillaud H, Levantal O, Pariente JL, Ballanger P. Characterization of urinary calculi: in vitro study of "twinkling artifact" revealed by color-flow sonography. AJR Am J Roentgenol. 1998;171:1055-60.
20. Turrin A, Minola P, Costa F, Cerati L, Andrulli S, Trinchieri A. Diagnostic value of colour Doppler twinkling artefact in sites negative for stones on B mode renal sonography. Urol Res. 2007;35:313-17.
21. Dillman JR, Kappil M, Weadock WJ, Rubin JM, Platt JF, DiPietro MA, et al. Sonographic twinkling artifact for renal calculus detection: correlation with CT. Radiology. 2011 Jun;259:911-6.
22. Erwin BC, Carroll BA, Sommer FG. Renal colic: the role of ultrasound in initial evaluation. Radiology. 1984;152:147-50.
23. Amis ES Jr, Cronan JJ, Pfister RC, Yoder IC. Ultrasonic inaccuracies in diagnosing renal obstruction. Urology. 1982;19:101-5.
24. Tublin ME, Bude RO, Platt JF. The resistive index in renal Doppler sonography: where do we stand? AJR Am J Roentgenol. 2003;180:885-2.
25. Andrabi Y, Patino M, Das CJ, Eisner B, Sahani DV, Kambadakone A. Advances in CT imaging for urolithiasis. Indian J Urol. 2015;31:185-193.

26. Drake T, Jain N, Bryant T, Wilson I, Somani BK. Should low-dose computed tomography kidneys, ureter and bladder be the new investigation of choice in suspected renal colic?: A systematic review. Indian J Urol. 2014;30:137-43.
27. Masch WR, Cronin KC, Sahani DV, Kambadakone A. Imaging in Urolithiasis. Radiol Clin North Am. 2017;55:209-24.
28. Regan F, Kuszyk B, Bohlman ME, Jackman S. Acute ureteric calculus obstruction: unenhanced spiral CT versus HASTE MR urography and abdominal radiograph. Br J Radiol. 2005;78:506-11.
29. Fung GS, Kawamoto S, Matlaga BR, Taguchi K, Zhou X, Fishman EK, et al. Differentiation of kidney stones using dual-energy CT with and without a tin filter. Am J Roentgenol. 2012;198:1380-86.
30. Morhard D, Fink C, Graser A, Reiser MF, Becker C, Johnson TR. Cervical and cranial computed tomographic angiography with automated bone removal: Dual energy computed tomography versus standard computed tomography. Invest Radiol. 2009;44:293-97.
31. Pache G, Krauss B, Strohm P, Saueressig U, Blanke P, Bulla S, et al. Dual-energy CT virtual noncalcium technique: Detecting posttraumatic bone marrow lesions- feasibility study. Radiology. 2010;256:617-24.
32. Ascenti G, Mazziotti S, Lamberto S, Bottari A, Caloggero S, Racchiusa S, et al. Dual-energy CT for detection of endoleaks after endovascular abdominal aneurysm repair: Usefulness of coloured iodine overlay. AJR Am J Roentgenol. 2011;196:1408-14.
33. Sanghavi PS, Jankharia BG. Applications of dual energy CT in clinical practice: A pictorial essay. Indian J Radiol Imaging. 2019;29:289-98.
34. Thomas C, Heuschmid M, Schilling D, Ketelsen D, Tsiflikas I, Stenzl A, et al. Urinary calculi composed of uric acid, cystine, and mineral salts: differentiation with dual-energy CT at a radiation dose comparable to that of intravenous pyelography. Radiology. 2010;257:402-09.

35. Ascenti G, Siragusa C, Racchiusa S, Ielo I, Privitera G, Midili F, et al. Stone- targeted dual-energy CT: A new diagnostic approach to urinary calculosis. AJR Am J Roentgenol. 2010;195:953-58.
36. Cellina M, Bausano MV, Pais D, Chiarpenello V, Costa M, Vincenzo Z, et al. Dual-Energy CT Applications in Urological Diseases. Appl Sci. 2023;13:7653.
37. Li ZX, Jiao GL, Zhou SM, Cheng ZY, Bashir S, Zhou Y. Evaluation of the chemical composition of nephrolithiasis using dual-energy CT in Southern Chinese gout patients. BMC Nephrol. 2019;20:273.
38. Kambadakone AR, Eisner BH, Catalano OA, Sahani DV. New and evolving concepts in the imaging and management of urolithiasis: Urologists' perspective. Radiographics.2010;30:603-23.
39. Primak AN, Ramirez Giraldo JC, Liu X, Yu L, McCollough CH. Improved dual-energy material discrimination for dual-source CT by means of additional spectral filtration. Med Phys. 2009;36:1359-69.
40. Stolzmann P, Scheffel H, Rentsch K, Schertler T, Frauenfelder T, Leschka S, et al. Dual-energy computed tomography for the differentiation of uric acid stones: ex vivo performance evaluation. Urol Res. 2008;36:133-8.
41. Shinde S, Al Balushi Y, Hossny M, Jose S, Al Busaidy S. Factors affecting the outcome of extracorporeal shockwave lithotripsy in urinary stone treatment. Oman Med J. 2018;33:209–17.
42. Renner C, Rassweiler J. Treatment of renal stones by extracorpo- real shock wave lithotripsy. Nephron. 1999;8:71–81.
43. Duan X, Li Z, Yu L, Leng S, Halaweish AF, Fletcher JG, et al. Characterization of Urinary Stone Composition by Use of Third-Generation Dual-Source Dual-Energy CT With Increased Spectral Separation. AJR Am J Roentgenol. 2015;205:1203-7.
44. Wisenbaugh ES, Paden RG, Silva AC, Humphreys MR. Dual-energy vs conventional computed tomography in determining stone composition. Urology. 2014;83:1243-7.
45. Zheng X, Liu Y, Li M, Wang Q, Song B. Dual-energy computed tomography for characterizing urinary calcified calculi and uric acid calculi: A meta-analysis. Eur J Radiol. 2016;85:1843-48.

46. Habashy D, Xia R, Ridley W, Chan L, Ridley L. Impact of dual energy characterization of urinary calculus on management. J Med Imaging Radiat Oncol. 2016;60:624-31.
47. Dawoud MM, Dewan KA, Zaki SA, Sabae MA. Role of dual energy computed tomography in management of different renal stones. The Egyptian Journal of Radiology and Nuclear Medicine. 2017;48:717-27.
48. Erdogan H, Temizoz O, Koplay M, Ozturk B. In Vivo Analysis of Urinary Stones With Dual-Energy Computed Tomography. J Comput Assist Tomogr. 2019;43:214-19.
49. Dawoud MM, Dewan KA, Zaki SA, Sabae MA. Role of dual energy computed tomography in management of different renal stones. The Egyptian Journal of Radiology and Nuclear Medicine. 2017;48:717-27.
50. Mehra S. Role of dual-energy computed tomography in urolithiasis. Journal of Gastrointestinal and Abdominal Radiology. 2022;5:121-6.
51. Rudenko V, Serova N, Kapanadze L, Taratkin M, Okhunov Z, Leonard SP, et al. Dual-Energy Computed Tomography for Stone Type Assessment: A Pilot Study of Dual-Energy Computed Tomography with Five Indices. J Endourol. 2020;34:893-99.
52. Taha M, Shawky M, Abd Ella MD, Tarek F. Role of Dual Energy Computed Tomography in Evaluation of Renal Stones. Med J Cairo Univ. 2021;89:1349-57.
53. Shalini S, Arunachalam VK, Varatharajaperumal RK, Mehta P, S T, Cherian M. The role of third-generation dual-source dual-energy computed tomography in characterizing the composition of renal stones with infrared spectroscopy as the reference standard. Pol J Radiol. 2022 11;87:172-76.
54. Bharati A, Rani Mandal S, Gupta AK, Seth A, Sharma R, Bhalla AS, et al. Non-Invasive characterisation of renal stones using dual energy CT: A method to differentiate calcium stones. Phys Med. 2022;101:158-164.

55. Euler A, Wullschleger S, Sartoretti T, Müller D, Keller EX, Lavrek D, et al. Dual-energy CT kidney stone characterisation diagnostic accuracy be achieved at low radiation dose? EurRadiol. 2023;33:6238-44.
56. El-Sayed MZ, El Safwany MM, Kandil BA, Ali MA. Characterization of Renal Stone Composition Using the Dual-Energy Technique of Computed Tomography: An in Vitro Study. Egypt J Phys. 2023;51:101-113.
57. Johnson JP, Dhall A, Chawla A, Prakashini K. Renal calculus composition analysis using dual-energy CT: a prospective observational study. Afr J Urol. 2024;30:19.
58. Panchal A, Gautam R, Ray A, Narayan P, Pillai R, Mapari M. Clinical profile of patients with renal stone disease in a tertiary care hospital in Navi Mumbai. Int J Surg Sci. 2020;4:288-91.
59. Patel PB. Analysis of Kidney Stones Prevalent in Saurashtra Region (Doctoral dissertation, Saurashtra University).
60. Gillen DL, Coe FL, Worcester EM. Nephrolithiasis and increased blood pressure among females with high body mass index. Am J Kidney Dis. 2005;46:263-9.
61. Maharaul HH, Brar G, Dhorajia D. Clinical profile and management of nephrolithiasis. Int J Health Sci. 2022;6:711-25.
62. Bhawani SS, Jehangir M, Masood M, Dar SA, Syed SN. Dual-Energy Multidetector Computed Tomography: A Highly Accurate Non-Invasive Tool for in Vivo Determination of Chemical Composition of Renal Calculi. Galician medical journal. 2021;28:202134.
63. Manglaviti G, Tresoldi S, Guerrer CS, Di Leo G, Montanari E, SardanelliF, et al. In vivo evaluation of the chemical composition of urinary stones using dual-energy CT. AJR Am J Roentgenol. 2011;197:76-83.
64. Ilyas M, Dev G, Gupta A, Bhat TA, Sharma S. Dual-energy computed tomography: A reliable and established tool for *In vivo* differentiation of uric acid from nonuric acid renal Stones. Niger Postgrad Med J. 2018;25:52-59.

65. Baskararaj S, Narayana M, Prakash HS, Naganna HP, Gowda VM. Evaluation of Renal/Ureteric Calculus Composition using Dual-Energy Computed Tomography: A Cross-sectional Study. Biomed Res. 2023;12:1:4
66. Ansari MS, Gupta NP, Hemal AK, Dogra PN, Seth A, Aron M, et al. Spectrum of stone composition: structural analysis of 1050 upper urinary tract calculi from northern India. Int J Urol. 2005;12:12-16.
67. Rao MV, Agarwal JS, Taneja OP. Studies in urolithiasis: II. X-ray diffraction analysis of calculi from Delhi region. Indian J Med Res. 1976;64:102-7.
68. Ahlawat R, Goel MC, Elhence A. Upper urinary tract analysis using X-ray diffraction: results from tertiary referral center in North India. Natl Med J India. 1996;9:10–12.
69. Sharma RN, Shah I, Gupta S. Thermogravimetric analysis of urinary stones. Br J Urol. 1989;64:10–13.
70. Faridi MS, Singh KS. Preliminary study of prevalence of urolithiasis in North-Eastern city of India. J Family Med Prim Care. 2020;9:5939-43.
71. Rajeev TP, Singh Y, Barua SK, Sarma D. Correlative analysis between severity of urolithiasis and laboratory parameters and its implication in evaluation of the probable risk profile. World J Nephrol Urol. 2018;7:25-31.
72. Hallawee S. Urinary stone distribution in Samawah: Current status and variation with age and sex a cohort study Muthanna Med J. 2015;2:93–8.
73. Chand RB, Shah AK, Pant DK, Paudel S. Common site of urinary calculi in kidney, ureter and bladder region. Nepal Med Coll J. 2013;15:5-7.
74. Durgawale P, Shariff A, Hendre A, Patil S, Sontakke A. Chemical analysis of stones and its significance in urolithiasis. Biomed Res. 2010;21:305-10.

KEY TO MASTER CHART

1. M : Male
2. F : Female
3. PUJ : Pelvic Ureteric Junction
4. CaHA : Calcium Hydroxyapatite
5. CaOxalate : Calcium oxalate
6. AR : Attenuation Ratio

S NO	Name	Age/Gender	MRD	Location of calculus	Size of Calculus	Attenuation Ratio	Ct predicted type	Lab analysis type
1	JARNAIL KAUR	79/F	1372122	R- Renal Pelvis	15 X 10 MM	1.31	Ca Oxalate	Ca Oxalate
2	PARAMJIT KAUR	54/F	1536572	a)R-Staghorn calculus	5.5 X 4.2 MM	1.62	Ca HA	Ca Oxalate
				b) R- Lower Calyx	7 X 5 MM	1.4	Ca Oxalate	Ca Oxalate
3	KAVITA ADYA	45/F	1539758	R- Middle calyx	16 MM	1.57	Ca HA	Ca HA
4	JATINDER KAUMR	50/M	1611212	a) R- Upper Calyx	15 X 14 MM	1.0	URIC ACID	Uric acid
				b) L- Lower Calyx	16 mm	1.0	URIC ACID	Uric acid
				c) R- Middle Calyx	14 MM	1.31	Ca Oxalate	Ca Oxalate
5	TARSEM LAL	57/M	1612557	R- Pelvis	12 X 7 MM	1.56	Ca HA	Ca Oxalate
6	AMARJIT KAUR	57/F	1167560	a) R- Pelvis	7 X 5 MM	1.56	Ca HA	Ca Oxalate
				b) L- Middle Calyx	14 X 8 MM	1.54	Ca Oxalate	Ca Oxalate
				c) L- Lower Calyx	5 X 4 MM	1.64	Ca HA	Ca Oxalate
7	JASWINDER KAUR	37/F	757329	R- Upper Calyx	16 X 10 MM	1.53	Ca Oxalate	Ca Oxalate
8	CHARANJIT SINGH	57/M	1589426	L- Pelvis	13 MM	1.52	Ca Oxalate	Ca Oxalate
9	MANGAL PRASAD	70/M	1559790	a) L- PUJ	15 X 12 MM	2.0	Ca HA	Ca Oxalate
				b) L- Lower Calyx	11 X 8 MM	1.0	URIC ACID	Uric acid
				c)L- Middle Calyx	11 X 9 MM	1.1	URIC ACID	
10	DALJIT KAUR	54/F	1596936	a) R- Lower Calyx	11 X 8 MM	1.6	Ca HA	Ca Oxalate
				b) R- Upper ureter	12 X 10 MM	1.61	Ca HA	Ca HA
11	WAZIR AHMED	58/M	1580594	R- Renal Pelvis	14 X 12 MM	2.3	Ca HA	Mixed stone
12	MEENA BISHT	44/F	8790	R- PUJ	13 X 9 MM	1.51	Ca Oxalate	Ca Oxalate
13	MANJIT KAUR	75/F	1590503	a) R- Pelvis	15 X 9 MM	1.52	Ca Oxalate	Ca Oxalate
				b)R- Upper Calyx	5 X 6 MM	1.58	Ca HA	Ca HA
14	GURPREET SINGH	44/M	236636	a)R-Inf- Calyx	5 X 6 MM	1.6	Ca HA	Ca HA
				b)R-prox ureter	17 X 10 MM	1.59	Ca HA	Ca HA
15	LUCKY	13/M	811597	R- Pelvis	16 X 11 MM	1.54	Ca Oxalate	Ca Oxalate
16	HARVINDER KAUR	42/F	1577140	a) R- Pelvis	12 X 7 MM	1.55	Ca HA	Ca HA
				b) R- PUJ	5.7 X 6 MM	1.62	Ca HA	Ca HA
17	SOM RAJ	68/M	1546945	R- Pelvis	13 X 8 MM	1.54	Ca Oxalate	Ca Oxalate
18	SUKHWINDER SINGH	43/M	111127	a) R- Partial staghorn	19 X 15 MM	1.54	Ca Oxalate	Ca Oxalate
				b) R- Lower Calyx	18 X 8 MM	1.53	Ca Oxalate	Ca Oxalate
19	RAJESH GUPTA	52/M	1450665	R- partial staghorn	34 X 12 MM	1.52	Ca Oxalate	Uric acid
20	GURNAM SINGH	44/M	1441834	a) L- PUJ	11 X 9 MM	1.51	Ca Oxalate	Ca Oxalate
				b) L- Lower Calyx	8 X 7 MM	1.56	Ca HA	Ca Oxalate
21	TEJPAL SINGH	42/M	918304	R- inf. Calyx	18 X 9 MM	1.52	Ca Oxalate	Ca Oxalate
22	RANJAM CHALLANA	46/M	1517744	L- inf. Calyx	15 X 8 MM	1.53	Ca Oxalate	Ca Oxalate
23	RITA SINGLA	50/F	1434971	L- inf. Calyx	11 X 8 MM	1.55	Ca HA	Ca HA
24	PARKASH KAUR	71/F	1513519	L- Middle Calyx	20 X 21 MM	1.51	Ca Oxalate	Mixed stone
25	KAMALJIT KAUR	30/F	1494153	a) R- Lower Calyx	15 X 16 MM	1.59	Ca HA	Ca Oxalate
				b) R- Middle Calyx	10 X 7 MM	1.64	Ca HA	Ca Oxalate

S NO	Name	Age/Gender	MRD	Location of calculus	Size of Calculus	Attenuation Ratio	Ct predicted type	Lab analysis type
26	POONAM	55/F	1510633	a) L- Pelvis	12 X 7 MM	1.55	Ca HA	Ca HA
				b) L- Upper calyx	4 X 3.5 MM	1.51	Ca Oxalate	Ca Oxalate
27	SUKHDEV	64/M	1505728	L- PUJ	32 X 30 MM	1.39	Ca Oxalate	Mixed stone
38	PARDEEP SINGH	37/M	1490878	L- PUJ	13 X 8 MM	1.54	Ca Oxalate	Ca Oxalate
29	AMRINDER SINGH	34/M	1487506	a) L- staghorn calculus	22 X 15 MM	1.53	Ca Oxalate	Ca Oxalate
				b) L- Lower Calyx	5 X 6 MM	1.58	Ca HA	Calcium HA
30	RAJ KUMAR GUPTA	55/M	877619	R- Pelvis	21 X 18 MM	1.50	Ca Oxalate	Ca Oxalate
31	OM PARKASH	69/M	1517125	L- PUJ	21 X 11 MM	1.52	Ca Oxalate	Ca Oxalate
32	SIMRANJEEET SINGH	33/M	1532358	L- Lower Calyx	52 X 26 MM	1.4	Ca Oxalate	Ca Oxalate
33	PARDEEP KUMAR	50/M	4803	L- PUJ	15 X 10 MM	1.54	Ca Oxalate	Ca Oxalate
34	AMAN GOYAL	47/M	72041	a) R- Middle Calyx	6 X 5 MM	1.56	Ca HA	Ca Oxalate
				b)L- distal ureter	7 X 5 MM	1.58	Ca HA	Ca HA
35	GURMEET KAUR	55/F	1559117	a) R- Renal Pelvis	7 X 5 MM	1.54	Ca Oxalate	Ca Oxalate
				b) L- Middle Calyx	4 X 5 MM	1.48	Ca Oxalate	Ca Oxalate
36	ALOK KUMAR	58/M	1585013	a) R- Pelvis	20 X 15 MM	1.4	Ca Oxalate	Ca Oxalate
				b) L -distal ureter	8 X 7 MM	1.51	Ca Oxalate	Ca Oxalate
37	MOHAN ARORA	62/M	1595982	a) L- Pelvis	13 X 11 MM	1.48	Ca Oxalate	Ca Oxalate
				b) L- mid ureter	6 X 7 MM	1.51	Ca Oxalate	Ca Oxalate
38	DALJIT KAUR	54/F	1596936	a) R- Lower Calyx	11 X 8 MM	1.6	Ca HA	Ca HA
				b) R- mid ureter	12 X 10 MM	1.61	Ca HA	Ca HA
39	BALDEV SINGH	32/M	1451769	a) R- Renal Pelvis	11 X 6 MM	1.04	URIC ACID	Uric acid
				b) R- Lower Calyx	10 X 9 MM	1.02	URIC ACID	Uric acid
40	BHIM SAIN	63/M	1596631	L- Renal Pelvis	18 X 11 MM	1.49	Ca Oxalate	Ca Oxalate
41	GURVAIL SINGH	63/M	740871	L- Lower Calyx	6.1 X 5 MM	1.71	Ca HA	Ca HA
42	SWARAN SINGH	55/M	1561018	L- PUJ	13 X 9 MM	1.60	Ca HA	Ca HA
43	SHASHI PURI	55/F	1456756	R- Upper Calyx	10 X 17 MM	1.31	Ca Oxalate	Ca Oxalate
44	AMANDEEP SINGH	35/M	380226	a) R- Lower Calyx	12 X 9 MM	1.55	Ca HA	Mixed stone
				b) L- PUJ	7.8 X 6 MM	1.50	Ca Oxalate	Mixed stone
45	BALRAJ SINGH	56/M	1532267	L- Middle Calyx	11 X 10 MM	2.4	Ca HA	Mixed stone
46	SATISH KUMAR JAIN	65/M	910249	a) L- Renal Pelvis	15 X 13 MM	1.50	Ca Oxalate	Ca Oxalate
				b) R- distal ureter	12 X 7 MM	1.53	Ca Oxalate	Ca Oxalate
47	DAVINDER KAUR	45/F	1563967	R- Lower Calyx	5 X 4.8 MM	1.63	Ca HA	Ca Oxalate
48	ANJALI MALIK	39/F	1562091	a) L- PUJ	15 X 10 MM	1.54	Ca Oxalate	Ca Oxalate
				b) R- Middle Calyx	6 X 4 MM	1.59	Ca HA	Ca Oxalate
49	ARMAN	29/M	1408916	L- Upper calyx	11 X 10 MM	1.55	Ca HA	Ca HA
50	HARSH JHA	22/M	1582517	R- Lower Calyx	7.2 X 5 MM	1.60	Ca HA	Cal Oxalate
51	ANU BALA	47/F	1590399	L- Renal Pelvis	7 MM	1.58	Ca HA	Ca HA
52	BHAWNA GOYAL	33/F	1596916	L- Lower Calyx	5 X 4 MM	1.55	Ca HA	Ca Oxalate
53	DINESH KUMARI	64/F	1557931	L- Renal pelvis	7.7x 7mm	2.4	Ca HA	Ca oxalate

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Subject:: **Approval of Plan of Thesis.**

This is to inform you that the Faculty of Medical Sciences in its meeting held on 25.09.2023 has approved the plan of thesis of **Lovepreet Singh**, a student of your college for **MD Radio-diagnosis** along with the names of Supervisor/Co-Supervisor as under:-

Topic Plan of Thesis
Role of dual energy computed tomography (ct) in characterisation and management of renal stones .

Supervisor
Dr. Kavita Saggar
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Co-Supervisor:-
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The student may submit the thesis in triplicate alongwith the plan in triplicate also, to the Controller of Examinations, BFUHS, Faridkot, at least six months before the commencement of theory examination, if he/she is otherwise eligible to take the examination. He /She may be directed to attach a photocopy of this letter with the forwarding letter while submitting thesis in the University along with the letter of approval of University for change of supervisor/Co-Supervisor, change of topic, if any.

Controller of Examinations

Note :

1. *If any discrepancy found regarding topic of thesis or Supervisor/Co-Supervisor, inform undersigned within one month after issue of this letter.*

ROLE OF DUAL ENERGY COMPUTED TOMOGRAPHY (CT) IN CHARACTERISATION AND MANAGEMENT OF RENAL STONES

THESIS PROPOSAL

FOR APPROVAL OF SUBJECT OF THESIS TO BE SUBMITTED IN

PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MD

IN

RADIODIAGNOSIS

OF THE

BABA FARID UNIVERSITY OF HEALTH SCIENCES

FARIDKOT

OCTOBER, 2022

DR. LOVEPREET SINGH

DEPARTMENT OF RADIODIAGNOSIS
DAYANAND MEDICAL COLLEGE AND HOSPITAL
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ABSTRACT OF PLAN OF THESIS

Title	ROLE OF DUAL ENERGY COMPUTED TOMOGRAPHY (CT) IN CHARACTERISATION AND MANAGEMENT OF RENAL STONES
For the degree of	MD (Radiodiagnosis)
Name of the candidate	Dr. Lovepreet Singh
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INTRODUCTION: Nephrolithiasis is a common clinical problem . The most common chemical composition that forms the stones are calcium oxalate(70%), calcium phosphate(20%), Uric acid(8%), and cystine (2%).Dual energy CT relies on chemical characterisation of renal stones in addition to assessment of the anatomical data as size, site and character of the stone surface. The dual energy CT has been reported as having a near 100% sensitivity and specificity for characterising the chemical composition of renal stones more than 3 mm. A reliable determination of the chemical type of stone help the clinician to better satisfy the treatment options for the patient such as those composed of uric acid, may be treated medically and may not require surgery. Dual energy CT is expected to replace conventional single energy CT as an important imaging modality in evaluating patients with suspected urinary calculi as it provides images that pinpoint the same anatomical information as well stone composition.

AIM OF STUDY: The aim of present study is to determine the role of dual energy in characterisation and management of renal stones.

Materials and Methods: Patient diagnosed with renal calculi and scheduled to undergo surgical extraction of stones in Dayanand Medical College and Hospital will be included in the study. After the characterisation of the calculus via Dual energy computed tomography, surgical extraction will be done. The chemical composition of the stones will be determined by laboratory analysis and will be compared with the findings of DECT.

Keywords: Dual energy ratio, Dual energy computed tomography, stone attenuation value, nephrolithiasis

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CERTIFICATE OF FACILITIES AVAILABLE

This is to certify that the facilities for work on the subject of thesis titled **"ROLE OF DUAL ENERGY COMPUTED TOMOGRAPHY (CT) IN CHARACTERISATION AND MANAGEMENT OF RENAL STONES"** exist in the Department of Radiodiagnosis, DMC&H, Ludhiana and will be provided to the candidate. We will see that the data being included in the thesis is genuine and is collected by the candidate himself under our supervision and guidance.

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APPROVAL PROFORMA
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Date of enrollment	7th March, 2022
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PROFORMA FOR REGISTRATION OF SUBJECT FOR DISSERTATION

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4	DATE OF ADMISSION OF COURSE	07/03/2022
5	TITLE OF THE TOPIC	ROLE OF DUAL ENERGY COMPUTED TOMOGRAPHY IN CHARACTERISATION AND MANAGEMENT OF RENAL STONES

6. BRIEF RESUME OF THE INTENDED WORK

6.1 NEED FOR THE STUDY

Worldwide, the incidence and prevalence of nephrolithiasis ranges from 1-13%, with decreasing rates from United states (7-13%) to Europe (5-9%) and Asia (1-5%).[1] Among the urologic diseases, nephrolithiasis is the most common in Asia.[2] Such differences in the rates among various regions are accounted by the difference in the genetics, age, climate, diet, race and metabolic diseases.[3]

Urinary calculi are crystalline structures composed most commonly of calcium oxalate salts.[4] The course of management of urinary stones depends on a host of factors including location, size, composition, degree of obstruction, symptom severity, patient expectations, associated infections, other anatomical and medical issues and technical factors.[5]

Commonly, eight minerals form the components of urinary stones.[6] Laboratory chemical analysis requires the use of sophisticated techniques, such as X-ray diffraction or different types of spectroscopy. In addition, laboratory assessment of the stones is done after the stones removal and thus are not helpful in pre- determination and selection of the treatment.[7]

DECT has emerged as a viable option that can be helpful in determining the composition of urinary stones with precision under in-vivo conditions itself.[8]

DECT is a simple, cost-effective and new technique which works on the principle of using two spectral X-ray beams (140kV and 80-100kV) to obtain two different images of the same tissue/region based on the absorption and attenuation index of the different material compositions. Based on this principle, DECT has been put to use in material differentiation (bone removal in angiography.[9], bone marrow oedema [10], metal artefact

reduction[11], material decomposition and iodine mapping (among lesions of lung, liver, adrenal and bowel pathologies)[12] and material separation (characterisation of urinary stones). [6,13,14]

Of all the technologies available, DECT is currently the most successful for achieving element decomposition. Since DECT acquisitions are at two different energy levels, the second attenuation measurement is made at a differing tube potential, in fact at a lower energy spectrum, which enables quantification of composition of elements that have similar electron densities but varying photon absorption, thereby providing differentiation between materials.[15] This is especially useful for materials with similar beam attenuation but different atomic numbers, such as iodinated contrast material and calcium. In renal stone evaluation, this ability of DECT is again extremely useful to identify chemical composition of stones and give preoperative analysis differentiating calcium containing stones, separate from cystine stones.[16]

Dual-source CT uses two independent X- ray tubes, mounted in the same gantry positioned orthogo- nal to each other, each X-ray source having its own detectors and own high voltage generator. Each X-ray source is operat- ed at a different tube potential and tube current value. The key technical aspect of DECT is simultaneous acquisition at different tube potentials, prior to table incrementation to reduce motion artifacts. The dual source enables superior image quality due to spectral separation by spectral filtration for each tube detector pair. This allows for higher signal to noise ratio and better image quality. Another advantage of dual-source CT is effective utilization of scatter generated from one tube being detected by the orthogonally placed second tube and reduction in spectral separation. Thus, material decomposition is achieved with little loss of temporal or spatial resolution.[17]

Composition of renal stone can be assessed on DECT to differentiate between calcium-contain- ing stones and uric acid stones, as for both types of stones different management principles are followed. The elements contributing to formation of renal stones are calcium, oxalate, urate, cystine, xanthine, and phosphate, with maximum renal stones being of calcium oxalate/phosphate composition (80%); 5 to 10% are uric acid stones, 5 to 15% are struvite, that is, magnesium ammonium phosphate stones; 1% are cystine stones; and xanthine, guaifenesin contribute 1% of chemical composition of urinary stones.[18]

The characteristics of renal stone that are considered before selecting a treatment approach for renal calculi by the urologist are the stone size, number, location in the calyx, and composition, along with renal anatomy and the clinical factors. These parameters are helpful for treating surgeons in not only planning an appropriate management for patient but also in predicting the success of the various procedures like ESWL, flexible ureterorenoscopy, or PCNL.

Keeping in view the importance of urinary stone composition in determining the management and treatment course of patients, dual energy CT could be helpful in giving right direction to the treatment planning and reducing the load of unnecessary surgical interventions or in specifying the surgical intervention need. Hence, the present study was planned with an aim to determine the pure composition of renal stones with DECT.

6.2 REVIEW OF LITERATURE

Thomas C et al, Ascenti G et al., has been successful in characterisation of renal stones with DECT.[13,14] In another study, Li ZX, specifically used DECT to differentiate uric acid stones from non-uric acid stones in the patients with Gout and found significant results.[6]

Kambadakone AR et al., showed that uric acid stones (<400 HU) are treated by alkalinization of the urine that facilitates dissolution, cystine stones, non-uric acid stones (>1000 HU, >1 cm) are managed with ureteroscopy, or Percutaneous Nephrolithotomy (PCNL), and non-cystine non-uric acid stones (<1000 HU, <1 cm) can be best managed with Shock Wave Lithotripsy (SWL), or ureteroscopy.[19]

Primak AN, stated that The ability of DECT to discriminate between two materials is highly dependent on the difference between each material's characteristic CT number ratio (CTR), which is defined as the CT number of a given material in the low energy image to the CT number of the same material in the high-energy image.[20]

Stolzmann et all said identifying uric acid calculi with the help of DE ratios can change patient management. Patients with familial meta-bolic diseases tend to benefit from DECT. This is especially so for patients suffering from cystinuria, who develop renal calculi that are composed of cystine. These can be treated medically using captopril, and more invasive treatments such as ESWL or PCNL, which are both expensive and have potential complications including renal hemorrhage, fibro- sis, or hypertension, can be avoided in these patients.[21]

Stolzmann et al demonstrated that uric acid– and nonuric acid–containing stones can be accurately differentiated in an ex vivo setting by using a dual- energy CT approach with a dual-source CT scanner. They compared stones on the basis of differences in attenuation at 80

and 140 kV and found significantly higher attenuation among the stones that contained no uric acid.[17]

Shinde S, Al Balushi Y showed that Heterogeneity in stone composition renders a stone susceptible to fragmentation with treatment and hence warrants a mention in report, so that the urologist can target these stones with ESWL. Homogeneous stones, cystine stones as well as calcium-stones of certain attenua- tion, are extremely difficult to fragment with ESWL.[22]

Renner C, Rassweiler J. showed that Success of ESWL depends on stone compo-sition that affects the type of fragments produced on de-composition of the calculus. Denser calculi made of calcium phosphate or cysteine are resistant to breakage by ESWL and require surgery. Calcium-based stones include calcium oxa- late monohydrate, calcium oxalate dihydrate, and calcium phosphate stones. Calcium oxalate monohydrate, struvite, calcium oxalate dihydrate, and uric acid stones have a firm composition that may limit the success of ESWL. Cystine and calcium oxalate monohydrate calculi are resistant to frag-mentation and are treated by ESWL only when the stone burden is smaller than <1.5cm.[23]

Duan et al. reported that differentiation between uric and non–uric acid stones was improved by using third-generation dual-source DECT with increased spectral separation and that the third-generation units can be useful in reducing image noise in patients with large body habitus.[24]

Basha MA, AlAzzazy MZ reported Dual-energy ratios (DE ratios) are used to differentiate between calcium-based stones and uric acid stones. DE ratios obtained in a graphical format are the highlight of DECT equipment in urolithiasis imaging. The DE ratios are obtained by dividing the attenuation value of the calculus at 80 kV by its attenuation value at 140 kV. DE ratio greater than 1.24 is characteristic for calcium containing stones.[25]

Duan et al.[24] reported that Dual-energy CT (DECT) utilizes the x-ray attenuation information from two different beam energies to characterize chemical composition, and thus has the potential to overcome the limitations of single-energy CT. The principles of DE material decomposition were first described more than 30 years ago by Alvarez and Macovskil.[26]

Thomas C, Patschan O, Ketelsen D reported that The X-ray attenuation of chemical compositions de- pends on their density, on their atomic number and on the energy (X-ray spectrum) of the penetrating beam. The energy dependency of the attenuation is linked to the atomic number; with increasing atomic numbers of the penetrated chemical elements, the energy dependency of the attenuation also increases. In urinary calculi, various chemical elements can be found: While calcium oxalate (CaC2O4), calcium phosphate (Ca3(PO4)2) and cystine (C6H12N2O4S2) contain elements with high atomic num- bers (Ca: 20; S: 16; P: 15), uric acid (C5H4N4O3) and struvite ((NH4)MgPO4•6H2O) are mainly composed of elements with lower atomic numbers. Therefore, each of the above-described materials is expected to have its own attenuation profile when examined with different X-ray energies. Dual-energy (DE) CT is thus a promising approach to non-invasively analyze the chemical composi- tion of urinary calculi.[27]

Boll et al tested the capability of dual-source CT imaging to facilitate dif- ferentiation between uric acid, cystine, struvite, calcium oxalate, calcium phos- phate, and brushite ex vivo. The stones were scanned at 80 and 140 kV, and the differences in attenuation values and attenuation ratios for each stone were compared. The authors found that the differences in attenuation at each kilo- voltage level, as well as the differences in low- to high-kilovoltage–based attenua- tion ratios between calcium oxalate and calcium phosphate, were significant.[28]

Grosjean et al analyzed the chem- ical composition of 241 renal stones that had been removed from humans and placed in a jelly phantom on a dynamic platform designed to simulate the breath- ing motion that is characteristic of in vivo studies. They performed sequential CT scan acquisitions at two energy levels, 80 and 120 kV, and subtracted attenua- tion values on low-energy images from at- tenuation values on high-energy images. On images obtained in the still phan- tom, uric acid, cystine, struvite, weddel- lite, brushite, and whewellite appeared as distinct groups. However, when slight platform motion, similar to the motion with respiration, was applied during im- age acquisition, the attenuation values were significantly different from those obtained with no motion.[29]

Flohr TG, McCollough CH reported that Dual-energy CT, by facilitating low- and high-energy scanning during a sin- gle acquisition, has inherent capability to help differentiate different materi- als that have similar electron densities but varying photon absorption.[30]

6.3 AIMS AND OBJECTIVES OF THE STUDY

The aim of present study is to determine the role of Dual energy computed tomography in characterisation and management of renal stones.

7.0 MATERIALS AND METHODS:

Patient diagnosed with renal calculi and scheduled to undergo surgical extraction of stones in Dayanand Medical College and Hospital will be included in the study. After the characterisation of the calculus via Dual energy computed tomography, surgical extraction will be done. The chemical composition of the stones will be determined by laboratory analysis and will be compared with the findings of DECT.

7.1 SOURCE OF DATA

The study will be conducted on patients who are diagnosed with renal calculi and scheduled to undergo surgical extraction of stones in Dayanand Medical College and Hospital.

7.2 METHOD OF COLLECTION OF DATA

Inclusion Criteria:

Patient diagnosed with renal calculi on ultrasound, plain x-ray or Intravenous Pyelogram (IVP) and scheduled to undergo surgical extraction of stones, patient willing to be part of the study.

Exclusion Criterion

Pregnancy, previously diagnosed cases of nephrolithiasis (on treatment), medically managed patients, patient not willing to give consent, patients in whom laboratory analysis of the stone is not feasible.

DURATION OF STUDY- One and a half years.

OUTCOME: The high precision of DECT in characterising the chemical nature of the renal stones and determining the management plan .

STATISTICAL ANALYSIS: Data will be described in terms of range; mean $_{+/-}$ standard deviation (+/-) frequencies (percentages) as appropriate. All statistical calculations will be done using SPSS (Statistical Package for the Social Science) SPSS 21 version statistical program for Microsoft Windows

7.3 DOES THE STUDY REQUIRE ANY INVESTIGATIONS OR INTERVENTIONS TO BE CONDUCTED ON PATIENTS OR OTHER HUMANS OR ANIMALS? IF SO, PLEASE DESCRIBE BRIEFLY.

No.

7.4 HAS ETHICAL CLEARANCE BEEN OBTAINED FROM YOUR INSTITUTION IN CASE OF 7.3?

Yes, Attached herewith

8. LIST OF REFERENCES

1. Sorokin I, Mamoulakis C, Miyazawa K, Rodgers A, Talati J, Lotan Y. Epidemiology of stone disease across the world. World J Urol. 2017;35:1301-20.
2. Liu Y, Chen Y, Liao B, Luo D, Wang K, Li H et al. Epidemiology of urolithiasis in Asia. Asian J Urol. 2018;5:205-14.
3. Alelign T, Petros B. Kidney Stone Disease: An Update on Current Concepts. Adv Urol. 2018;2018:3068365.
4. Sohgaura A, Bigoniya P. A Review on Epidemiology and Etiology of Renal Stone. Am J Drug Discov Dev. 2017;7:54-62.
5. Romero V, Akpinar H, Assimos DG. Kidney Stones: A Global Picture of Prevalence, Incidence, and Associated Risk Factors. Rev Urol. 2010;12:e86-96.
6. Li ZX, Jiao GL, Zhou SM, Cheng ZY, Bashir S, Zhou Y. Evaluation of the chemical composition of nephrolithiasis using dual-energy CT in Southern Chinese gout patients. BMC Nephrol. 2019;20:273.
7. Miernik A, Eilers Y, Bolwien C, Lambrecht A, Hauschke D, Rebentisch G, et al. Automated analysis of urinary stone composition using Raman spectroscopy: Pilot study for the development of a compact portable system for immediate postoperative ex vivo application. J Urol. 2013;190:1895-900.
8. Fung GS, Kawamoto S, Matlaga BR, Taguchi K, Zhou X, Fishman EK et al. Differentiation of kidney stones using dual-energy CT with and without a tin filter. Am J Roentgenol. 2012;198:1380-86.
9. Morhard D, Fink C, Graser A, Reiser MF, Becker C, Johnson TR. Cervical and cranial computed tomographic angiography with automated bone removal: Dual energy computed tomography versus standard computed tomography. Invest Radiol. 2009;44:293-97.
10. Pache G, Krauss B, Strohm P, Saueressig U, Blanke P, Bulla S, et al. Dual-energy CT virtual noncalcium technique: Detecting

posttraumatic bone marrow lesions- feasibility study. Radiology. 2010;256:617-24.

11. Ascenti G, Mazziotti S, Lamberto S, Bottari A, Caloggero S, Racchiusa S, et al. Dual-energy CT for detection of endoleaks after endovascular abdominal aneurysm repair: Usefulness of coloured iodine overlay. AJR Am J Roentgenol. 2011;196:1408-14.
12. Sanghavi PS, Jankharia BG. Applications of dual energy CT in clinical practice: A pictorial essay. Indian J Radiol Imaging. 2019;29:289-98.
13. Thomas C, Heuschmid M, Schilling D, Ketelsen D, Tsiflikas I, Stenzl A, et al. Urinary calculi composed of uric acid, cystine, and mineral salts: differentiation with dual-energy CT at a radiation dose comparable to that of intravenous pyelography. Radiology. 2010;257:402-09.
14. Ascenti G, Siragusa C, Racchiusa S, Ielo I, Privitera G, Midili Fet al. Stone- targeted dual-energy CT: A new diagnostic approach to urinary calculosis. AJR Am J Roentgenol. 2010;195:953-58.
15. Graser A, Johnson TR, Bader M, Staehler M, Haseke N, Nikolaou K, et al. Dual energy CT characterization of urinary calculi: initial in vitro and clinical experience. Investigative radiology. 2008;43:112-9.
16. Boll DT, Patil NA, Paulson EK, Merkle EM, Simmons WN, Pierre SA, et al. Renal stone assessment with dual-energy multidetector CT and advanced postprocessing techniques: improved characterization of renal stone composition—pilot study. Radiology. 2009;250:813-20.
17. Mileto A, Ananthakrishnan L, Morgan DE, Yeh BM, Marin D, Kambadakone AR. Clinical implementation of dual-energy CT for gastrointestinal imaging. AJR Am J Roentgenol 2021;217:651–6
18. Miller NL, Lingeman JE. Management of kidney stones. BMJ 2007; 334:468–72

19. Kambadakone AR, Eisner BH, Catalano OA, Sahani DV. New and evolving concepts in the imaging and management of urolithiasis: Urologists perspective. Radiographics.2010;30:603-23.
20. Primak AN, Ramirez Giraldo JC, Liu X, Yu L, McCollough CH. Improved dual-energy material discrimination for dual-source CT by means of additional spectral filtration. Med Phys. 2009;36:1359–69.
21. Stolzmann P, Scheffel H, Rentsch K, Schertler T, Frauenfelder T, Leschka S, et al. Dual-energy computed tomography for the differentiation of uric acid stones: ex vivo performance evaluation. Urological research. 2008;36:133-8.
22. Shinde S, Al Balushi Y, Hossny M, Jose S, Al Busaidy S. Factors affecting the outcome of extracorporeal shockwave lithotripsy in urinary stone treatment. Oman Med J 2018;33:209–217.
23. Renner C, Rassweiler J. Treatment of renal stones by extracorpo- real shock wave lithotripsy. Nephron 1999;81:71–81
24. Duan X, Li Z, Yu L, Leng S, Halaweish AF, Fletcher JG, et al. Characterization of urinary stone composition by use of third-generation dual-source dual-energy CT with increased spectral separation. AJR. American journal of roentgenology. 2015;205:1203-7
25. Basha MA, AlAzzazy MZ, Enaba MM. Diagnostic validity of dual-energy CT in determination of urolithiasis chemical composition: in vivo analysis. Egypt J Radiol Nucl Med 2018;49:499–508
26. Alvarez RE, Macovski A. Energy-selective reconstructions in X-ray computerized tomography. Phys Med Biol. 1976;21:733–44.
27. Thomas C, Patschan O, Ketelsen D, Tsiflikas I, Reimann A, Brodoefel H, et al. Dual-energy CT for the characterization of urinary calculi: in vitro and in vivo evaluation of a low-dose scanning protocol. European radiology. 2009;19:1553-9.
28. Boll DT, Patil NA, Paulson EK, et al. Renal stone assessment with dual-energy multide- tector CT and advanced

postprocessing tech- niques: improved characterization of renal stone composition—pilot study. Radiology 2009;250:813–20.

29. Grosjean R, Sauer B, Guerra RM, Daudon M, Blum A, Felblinger J, et al. Characterization of human renal stones with MDCT: advantage of dual energy and limitations due to respiratory motion. AMERICAN JOURNAL OF ROENTGENOLOGY-NEW SERIES-. 2008;190:720-8.
30. Flohr TG, McCollough CH, Bruder H, Petersilka M, Gruber K, Süβ C, et al. First performance evaluation of a dual-source CT (DSCT) system. European radiology. 2006;16:256-68.

PROFORMA

Sr. No.

Name:

Age/gender:

Mrd no.-

Address:

Date:

Chief Complaints :

Previous History:

S. no	Location of calculus	Size of calculus	Low energy attenuation value	High energy attenuation value	Attenuation ratio	CT predicted stone type	Lab analysis type

SIGNATURE OF CANDIDATE SIGNATURE OF SUPERVISOR

SIGNATURE OF CANDIDATE SIGNATURE OF SUPERVISOR

INFORMED PATIENT CONSENT

Date: _____

I……..D/o, W/o, S/o……. am willing to participate in the study **"ROLE OF DUAL ENERGY COMPUTED TOMOGRAPHY (CT) IN CHARACTERISATION AND MANAGEMENT OF RENAL STONES"** The procedure with its complications has been explained to me in local vernacular language. I have fully understood that no special tests and extra expenditure in any form, merely for the purpose of thesis is being carried out. I am free to opt out the study any time without assigning any reason.

…… ……

Signature of the Witness Signature of the patient

Name:

Signature of Candidate Signature of Supervisor

मरीज अनुमति फार्म

तिथि _____

मैं _____ पत्नी/पुत्र/पुत्री _____

निवासी _____ इस शोधकार्य **"ROLE OF DUAL ENERGY COMPUTED TOMOGRAPHY (CT) IN CHARACTERISATION AND MANAGEMENT OF RENAL STONES"** में भाग लेने के लिए सहमत हूँ। मैं इस शोधकार्य में भाग लेने के लिए अपनी स्वेच्छा से तैयार हूँ। मैं पुष्टि करता/करती हूँ की यह स्वीकृति देने के लिए मुझे कोई आर्थिक प्रलोभन नहीं दिया गया और न ही दबाव डाला गया है। मुझे इस शोधकार्य का उद्देश्य स्पष्ट कर दिया गया है और मुझे यह विश्वास है की यह विज्ञान और मानवता के लाभ के लिए है। मुझे इस शोधकार्य में होने वाले जोखिम के बारे में समझा दिया गया है और मेरी समझ में यह जोखिम बहुत मामुली है।

मैं इस शोधकार्य में भाग लेने के सम्बन्ध में किसी भी समय अपनी अस्वीकृति व्यक्त कर सकता/सकती हूँ और मेरे अस्वीकृति व्यक्त करने का मेरे इलाज पर कोई प्रभाव नहीं पड़ेगा।

_____ _____

गवाह के हस्ताक्षर रोगी के हस्ताक्षर/अंगूठे का निशान

नाम: नाम:

_____

अन्वेषक के हस्ताक्षर

_____

विद्यार्थी के हस्ताक्षर

ਮਰੀਜ਼ ਰਜ਼ਾਮੰਦੀ ਫਾਰਮ

ਮਿਤੀ_____

ਮੈ_____ਪਤਨੀ/ਪੁੱਤਰ/ਪੁੱਤਰੀ_____

ਵਾਸੀ _____

“ROLE OF DUAL ENERGY COMPUTED TOMOGRAPHY IN CHARACTERISATION AND MANAGEMENT OF RENAL STONES” ਤੇ ਚਲ ਰਹੀ ਖੋਜ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਰਜ਼ਾਮੰਦ ਹਾਂ। ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਮੈ ਆਪਣੀ ਮਰਜ਼ੀ ਨਾਲ ਤਿਆਰ ਹਾਂ। ਮੈ ਇਹ ਦਸਣਾ ਚਾਹੁੰਦਾ ਹਾਂ/ ਚਾਹੁੰਦੀ ਹਾਂ ਕੇ ਇਹ ਰਜ਼ਾਮੰਦੀ ਦੇਣ ਵਾਸਤੇ ਮੈਨੂ ਕਿਸੇ ਵੀ ਤਰਾਂ ਦਾ ਲੋਭ-ਲਾਲਚ ਨਹੀ ਦਿੱਤਾ ਗਿਆ ਅਤੇ ਨਾ ਹੀ ਕੋਈ ਦਬਾ ਪਾਇਆ ਗਿਆ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਦਾ ਮਨੋਰਥ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਭਰੋਸਾ ਦਵਾਇਆ ਗਿਆ ਹੈ ਕੇ ਇਹ ਖੋਜ ਵਿਗਿਆਨ ਅਤੇ ਮਾਨਵਤਾ ਦੀ ਭਲਾਈ ਲਈ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਵਿਚ ਹੋਣ ਵਾਲੇ ਖਤਰੇ ਬਾਰੇ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਯਕੀਨ ਹੈ ਕੇ ਇਹ ਖਤਰਾ ਬਹੁਤ ਮਾਮੂਲੀ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਦਾ ਢੰਗ – ਤਰੀਕਾ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ।

ਮੈ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਬਾਰੇ ਆਪਣੀ ਰਜ਼ਾਮੰਦੀ ਕਿਸੇ ਵੀ ਸਮੇ ਵਾਪਸ ਲੈ ਸਕਦਾ ਹਾਂ/ ਸਕਦੀ ਹਾਂ ਅਤੇ ਮੇਰੀ ਰਜ਼ਾਮੰਦੀ ਵਾਪਸ ਲੈਣ ਦਾ ਮੇਰੇ ਇਲਾਜ ਤੇ ਕੋਈ ਅਸਰ ਨਹੀ ਹੋਵੇਗਾ।

_____ _____

ਗਵਾਹ ਦੇ ਹਸਤਾਖਰ ਮਰੀਜ਼ ਦੇ ਹਸਤਾਖਰ

ਮਿਤੀ_____ ਮਿਤੀ_____

ਪਤਾ _____ ਪਤਾ _____

_____

ਨਿਰੀਖਕ ਦੇ ਹਸਤਾਖਰ

_____

ਸਿਖਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ